Integration of Paramedic-led Echocardiography in Pulseless Electrical Activity (PEA) During Out-of-hospital Cardiac Arrest: An education and simulation study.

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Abstract

During out-of-hospital cardiac arrest, patients presenting in pulseless electrical activity (PEA) may receive inappropriate care if a manual pulse check determines pulselessness. This study created the Cardiac Arrest Focused Echocardiography (CAFE) exam incorporating a pre-imaging technique to reduce the time spent acquiring an ultrasound image. Paramedic participants were trained to use the CAFE exam and to record an 8 second image during the pulse check pause. The paramedic performing the CAFE exam is supernumerary to standard cardiac arrest proceedings and must not interrupt the delivery of cardiopulmonary resuscitation (CPR). Real-time ultrasound image interpretation during the CPR cycle determined the presence of a pericardial effusion, tamponade physiology, and heart function.

Research Aim. To determine if paramedics can acquire an ultrasound image during the 10 second pulse check pause in simulated PEA cardiac arrest. Secondary aims focus on ultrasound image acquisition quality, interpretation, and retention of learned knowledge.

Method. The study recruited 30 paramedics from Wellington, New Zealand. This study adhered to the reporting guidelines set by the International Network for Simulation-based Paediatric Innovation Research and Education (INSPIRE). Participants were divided into two equal groups and completed three trial phases between January to March 2022. Phase I involved an eLearning program covering ultrasound theory, ultrasound device orientation, echocardiogram views, PEA, cardiac arrest ultrasound, and cardiac arrest considerations for Māori. Phase II involved 4.5 hours of classroom theoretical and practical education, including competency-based assessments. The assessments included simulations testing hands-off time (HOT), pathological image interpretation, echocardiography (echo)

skills and a knowledge test. The phase II assessments were replicated in phase III to assess knowledge and skill retention.

Findings. The mean HOT was 9.6 seconds (*SD* = 2.9, 95% CI [9.3, 10.0]), with 47.7% of scans achieved within the 10 second pulse check pause. Image adequacy was measured using the Cardiac Ultrasound Structural Assessment Scale (CUSAS). The results showed that 73.9% (95% CI [67.8, 79.4]) met the desired standard of ≥ 3. Of the 243 CAFE exam interpretations paramedics were correct in 91.9% of cases (95% CI [88.5, 94.5]). The accuracy of interpreting left ventricular squeeze was relatively low, with overall accuracy at 73.6% (95% CI [67.6, 79.0]). In contrast, valvular opening was consistently high, with 100% (95% CI [95.8, 100]) of cases in phase II and 99.3% (95% CI [96.4, 99.9]) in phase III. Overall, the knowledge quiz showed 67.2% (95% CI [53.2, 79.3]) satisfying the ≥ 80% pass requirement. This result did not meet the study aim. A binary logistic regression explored the association between HOT, study phase and station compared with the comparison station. An odds ratio of 7.69 (95% CI [1.35, 9.09]) with the ‘person effect’ was associated with an increased HOT due to image acquisition difficulty for this station.

Conclusion. This study found that paramedics can acquire and interpret ultrasound images during pulse check pauses in simulated PEA cardiac arrest. Despite limited training, study participants averaged 9.6 seconds for ultrasound examinations, with 47.7% meeting the 9.99-second time limit. Paramedic participants demonstrated adequate image acquisition and strong interpretation abilities. The findings showed that most participants were able to retain acquired knowledge and skills with the education intervention offered, but others will require ongoing training and support.

This study highlights the potential of ultrasound application in PEA cardiac arrest, emphasising the need for strategies to optimise HOT and address challenges such as

equipment costs, educational standards, and clinical governance. Ultrasound use in out-of-hospital cardiac arrest should focus on improving patient assessment accuracy by providing clinical information for differential diagnoses, and guiding treatment and transport decisions.

Research Outputs

This research has been disseminated through presentations and by educating paramedics in out-of-hospital ultrasound use. This section details the author's contributions and achievements in point-of-care ultrasound, specifically the integration of ultrasound in cardiac arrest resuscitation.

Oral Presentations

- 15th July 2022, Australasian College of Paramedicine Research Symposium, Sunshine Coast https://paramedics.org/events/acprs2022.
- 19th August 2022, 3-minute Thesis Virtual Competition Doctoral Candidate Finalist. https://www.youtube.com/watch?v=P6L1mXrscYg.
- 30th August 2022, Aeromedical Society of Australasia, and Flight Nurses Association Conference. Presentation on 'Ultrasound in Cardiac Arrest'. https://www.aeromedconference.com/2022-program.
- 17th November 2022, Auckland University of Technology Postgraduate Research Symposium. Presentation on 'Ultrasound in Cardiac Arrest'.
- 3rd December 2022, Invited speaker at WINFOCUS World Point of Care Ultrasound Congress on the integration of ultrasound in PEA cardiac arrest. https://www.winfocusworldcongress.com/archive/congress-2022/.
- 25th May 2023, Australasian College of Paramedicine Critical Care Summit Tweed Heads Gold Coast. Presented as part of a team on 'The Art of Low Fidelity

Simulation' Also, part of a podcast recording 'This Emergency Life Raft' https://paramedics.org/ccs2023/schedule.

- 22nd July 2023, Australasian Society of Ultrasound in Medicine Christchurch. Presented on the 'Focus of Pocus' introducing the proposed Certificate in Prehospital Performed Ultrasound. https://asum.com.au/docs/Events/NZ2023-Conference-Programme.pdf.
- 12th August 2023, Emergency Ultrasound Group presenting on the 'Focus of Pocus' introducing the proposed Certificate in Prehospital Performed Ultrasound.
- 24th October 2023, Australasian Society of Ultrasound in Medicine conference in Sydney presenting the 'Focus of Pocus' introducing the proposed Certificate in Prehospital Performed Ultrasound.

Awards and Grants

- 15th July 2022, Best Higher Degree by Research Presentation. Australasian College of Paramedicine Research Symposium.
- 30th August 2022, Best Presentation Award, Flight Nurses Association Conference.
- Auckland University of Technology School of Clinical Sciences 2022. Performance Based Research Seed Fund recipient.
- Paramedics Australasia Travel Grant 2022.
- The Heart Foundation Travel Grant 2022.

Ultrasound Specific Education - Completed

- Certificate of completion 17th April 2021, Clinical Ultrasound POCUS New Zealand, Wellington, accredited provider 2-day course in clinical ultrasound.

- Certificate of Completion Physics 16 August 2021. Tutorials through the Australasian Society of Ultrasound in Medicine. Physics tutorials and exams one to three as part of the Certificate in Allied Health Performed Ultrasound certification program.
- Emergency Ultrasound Group Online POCUS Management Part one Workshop, 31st May 2022.
- Australasian College for Emergency Medicine certificates of completion:
    - 30th March 2022, Certificate of completion eFAST ultrasound.
    - 17th June 2022, Ultrasound Governance.
    - 18th June 2022, Focused Echocardiography in Life Support.
    - 18th June 2022, Lung Ultrasound.
- Certificate in Allied Health Performed Ultrasound eFAST with the Australasian Society of Ultrasound in Medicine 27th October 2022.
- Certificate in Allied Health Performed Ultrasound Vascular Access with the Australasian Society of Ultrasound in Medicine 31st August 2023.
- Emergency Ultrasound Group face-to-face POCUS Management Part two workshop, 8th August 2023.

Opportunities

- Postgraduate course lead and lecturer for the Paramedic Ultrasound Course at Auckland University of Technology 2021, 2022 and 2023 https://www.aut.ac.nz/__data/assets/pdf_file/0006/506841/RADY801-Ultrasound-Imaging-Paramedicine-2022.pdf.

- Emergency Ultrasound Group Instructor Team (voluntary) 2022 https://www.emugs.org/newzealand.
- Introduction of ultrasound into Wellington Free Ambulance.
- Advocating for a new certification pathway for prehospital providers through the Australasian Society of Ultrasound in Medicine.
- Sonographic Educator in the Wellington Emergency Department, 8 hours per week supporting the Clinical Ultrasound Lead, 1st August 2023.

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Attestation of Authorship

I hereby declare that this is submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or another institution of higher learning.

Signature:  Date: 13th June 2024

List of Abbreviations and Terms

AAA	=	Abdominal Aortic Aneurysm
A4C	=	Apical Four Chamber View
ACC	=	Accident Compensation Corporation
AED	=	Automated External Defibrillator
ACEM	=	Australasian College of Emergency Medicine
ACLS	=	Advanced Cardiovascular Life Support
APC	=	Annual Practicing Certificate
AHA	=	American Heart Association
ALS	=	Advanced Life Support
ANZCOR	=	Australian New Zealand Council of Resuscitation
AO	=	Aortic Outflow
AR	=	Auto Regressive
ASUM	=	Australasian Society of Ultrasound in Medicine
ATP	=	Authority To Practice
AUT	=	Auckland University of Technology
B Mode	=	Brightness Mode
BELS	=	Basic Echo in Life Support
CAFE	=	Cardiac Arrest Focused Echo
Cardiac Arrest	=	The sudden loss of heart function
CASA	=	Cardiac Arrest Sonographic Assessment
CAUSE	=	Cardiac Arrest Ultrasound Exam
CCF	=	Chest Compression Fraction
CCP	=	Critical Care Paramedic
CCPU	=	Certificate in Clinician Performed Ultrasound
CPPU	=	Certificate in Prehospital Performed Ultrasound
CI	=	Confidence Interval
CINAHL	=	Cumulative Index to Nursing and Allied Health Literature
CiT	=	Compressions in Target
CoSTR	=	Cardiovascular Care Science with Treatment Recommendations
CPA	=	Clinical Practice Advisor
CPD	=	Clinical Practice Development
CPP	=	Coronary Perfusion Pressure
CPR	=	Cardiopulmonary Resuscitation
CUSAS	=	Cardiac Ultrasound Structural Assessment Scale
DAG	=	Depth, Axis, and Gain
DA	=	Descending Aorta
EAS	=	Emergency Ambulance Service

EBSCO	=	Research database
ECG	=	Electrocardiogram
Echo	=	Echocardiography
ECUSAS	=	Echo Cardiac Structural Assessment Score
ECP	=	Extended Care Paramedic
eFAST	=	Extended Focused Assessment Sonography in Trauma
ED	=	Emergency Department
ELS	=	Echo Life Support
EMS	=	Emergency Medical Service
EMT	=	Emergency Medical Technician
$ETCO_2$	=	End Tidal Carbon Dioxide
FAST	=	Focused Assessment Sonography in Trauma
FELS	=	Focused Echo in Life Support
FEELS	=	Focused Echo Evaluation in Life Support
FEER	=	Focused Echo Evaluation in Resuscitation
FR	=	First Responder
GEE	=	Generalised Estimating Equation
GENMOD	=	A procedure enabling binary logistic regression for generalised models
GIF	=	Graphics Interchange Format
HEMS	=	Helicopter Emergency Medical Service
Hz	=	Hertz a unit of frequency
HPCCA	=	Health Practitioners Competence Assurance Act
HP-CPR	=	High Performance Cardiopulmonary Resuscitation
HOT	=	Hands Off Time
ICD	=	Implantable Cardioverter Defibrillator
ICP	=	Intensive Care Paramedic
ICU	=	Intensive Care Unit
ID	=	Identification
IFEM	=	International Federation for Emergency Medicine
ILCOR	=	International Liaison Committee on Resuscitation
INSPIRE	=	International Network for Simulation-based Paediatric Innovation Research and Education
IQR	=	Interquartile Range
IVC	=	Inferior Vena Cava
Karakia	=	Prayer
Kaunihera Manapou	=	Paramedic Council
Koha	=	Gift, donation
LA	=	Left Atrium
LV	=	Left Ventricle

Māori	=	Indigenous New Zealand People
MELAA	=	Middle Eastern, Latin American, and African
MV	=	Mitral Valve
MCQ	=	Multiple Choice Questions
mmHg	=	Millimetres of mercury
MHz	=	Mega Hertz
MOH	=	Manatū Hauora, Ministry of Health
MRN	=	Medical Record Number
MTA	=	Motor Trade Association
NZ	=	New Zealand
OHCA	=	Out of Hospital Cardiac Arrest
OSCE	=	Objective Structured Clinical Examination
OSAUS	=	Objective Structural Assessment in Ultrasound Skill
Paramedic	=	The term paramedic for this research refers to all practice levels of emergency medical technician, paramedic, and critical care paramedic.
PAUSE	=	Prehospital Assessment Ultrasound for Emergencies
PBRF	=	Performance Based Research Fund
PDF	=	Portable Document Format
P-PEAT	=	Prepare, Pre-image, Echo, Analyse, and Treatment
PE	=	Pulmonary Embolism
PEA	=	Pulseless Electrical Activity
PHUS	=	Prehospital Ultrasound
PLAS	=	Parasternal Long Axis
PLAX	=	Parasternal Long Axis (alternative to PLAS)
POCUS	=	Point Of Care Ultrasound
PRISMA	=	Preferred Reporting Items Systematic Reviews and Meta-Analysis
PTX	=	Pneumothorax
PubMed	=	Free full-text archive of biomedical and life sciences journal
PUCA	=	Paramedic Ultrasound in Cardiac Arrest
QIC	=	Quasi-likelihood Information Criterion
Q-Q	=	Quantile-Quantile Plot
QRS	=	The ventricular contraction (systole) consisting of the Q wave (first negative deflection) followed by the R wave (positive upward deviation).
RA	=	Right Atrium
REASON	=	Real-time Evaluation and Assessment Sonography Outcomes Network
ROC	=	Resuscitation Outcomes Consortium
ROSC	=	Return of Spontaneous Circulation
RV	=	Right Ventricle
SARS-CoV-2	=	The disease caused by severe acute respiratory syndrome Coronavirus 2
SAS	=	Statistical Analysis Software

SBR	=	Simulation Based Research
SESAME	=	Sequential Echographic Scanning Assessing Mechanism or Origin of Severe Shock of Indistinct Cause
SCOPUS	=	Large multidisciplinary database of peer-reviewed literature
SD	=	Standard Deviation
SHoC	=	Sonography in Hypotension and Cardiac Arrest
Sim	=	Simulation
SPSS	=	Statistical Package for Social Sciences
STROBE	=	Strenthening the Reporting of Observational Studies in Epidemology
StudyP	=	Study Participant
SUBX	=	Subxiphoid Four Chamber View
Te Tiriti o Waitangi	=	The Treaty of Waitangi
UOR	=	Unadjusted Odds Ratio
US-CAB	=	Ultrasound – Circulation, Airway and Breathing
VF	=	Ventricular Fibrillation
VT	=	Ventricular Tachycardia
Wairua	=	Pathway of spirits
WFA	=	Wellington Free Ambulance

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"This thesis is dedicated to my son Sam, who I hope has the opportunity to appreciate academia".

Ethics and Locality Approval

Ethics approval for this study was granted by the Auckland University of Technology (AUT) Ethics Committee on 30th of November 2021, ethics approval number 21/327 shown in Appendix A. Locality approval through Wellington Free Ambulance (WFA) was granted on 12th of September 2021 by the Executive Director of Quality, Improvement, and Innovation, P. Fake and Dr. Andy Swain as shown in Appendix B. A brief privacy analysis shown in Appendix C was also submitted and accepted by WFA.

The Mātauranga[1] Māori Committee was consulted on November 5th, 2020, with a focus on maintaining social and cultural sensitivity and adhering to the principles of the Te Tiriti o Waitangi[2] - The Treaty of Waitangi for the research being conducted. The consultation with the Mātauranga Māori Committee and WFA also addressed cultural awareness and sensitivity concerning cardiac arrest, ultrasound, and death in phase I of the eLearning Module. Yvonne Gemmell, Māori liaison for Wellington Free Ambulance, was involved in the eLearning process and offered cultural support during the trial phases. The Mātauranga Māori Committee consultation feedback is shown in Appendix D.

[1] Te reo Māori for knowledge and knowing.

[2] Te reo Māori for The Treaty of Waitangi.

Chapter 1 Introduction

This chapter comprises six sections. The first highlights the prevalence and outcomes of out-of-hospital cardiac arrest (OHCA) in New Zealand, emphasising pulseless electrical activity (PEA). This section also discusses key OHCA resuscitation techniques, including high performance cardiopulmonary resuscitation (HP-CPR), manual pulse checks, end tidal carbon dioxide ($ETCO_2$) monitoring, and the electrocardiograms (ECG) role in PEA diagnosis. The subsequent section frames the problem statement, underscoring its relevance in New Zealand. The third discusses ultrasound's role in paramedic practice, addressing the current protocols, challenges, and potential applications. The fourth section outlines the research aims, accompanied by an originality statement. The fifth section details New Zealand's ambulance services, covering strategy, workforce, Wellington Free Ambulance (WFA), and the geographical context. The final section concludes by outlining this thesis's structure.

1.1 Background Out-of-Hospital Cardiac Arrest in Australasia

Cardiac arrest is a life-threatening event, with ischemic heart disease considered the second leading cause of death nationwide (Dicker, Todd, et al., 2021). Cardiac arrest occurs when heart function, breathing, and consciousness are lost and is the most time-sensitive, life-threatening event a patient can suffer. There are two types of cardiac arrest: either with a shockable rhythm or a non-shockable rhythm. The first is where a defibrillator corrects an erratic electrical heart stimulation that cannot sustain circulation. The second is a non-shockable rhythm: either asystole, with no electrical activity or heart contraction, or pulseless electrical activity (PEA), with normal electrical rhythm but no heart contraction. To

determine the patient's underlying rhythm, the attending paramedic[3] interprets the ECG to decide if the patient is in a shockable or non-shockable rhythm.

In 2018, the Australia and New Zealand Resuscitation Outcomes Consortium reported that shockable rhythms, such as ventricular fibrillation (VF) and pulseless ventricular tachycardia (VT), account for 27.9% (2591 cases) of OHCA and can be reversed with defibrillation (Beck et al., 2018). In New Zealand, VF and VT account for 36.5% (738 cases) of cardiac arrests in the Hato Hone St John Ambulance Service and 36.4% (96 cases) in the WFA region. Across Australasia, asystole and PEA account for 47% (4369 cases) and 24.5% (2277 cases) of cardiac arrests, respectively. Hato Hone St John treats 40% of asystole (808 cases) and 21.5% of PEA (435 cases); WFA presents similar data with 43.1% of asystole but 36.4% for PEA (Beck et al., 2018). First responders, including the Fire and Emergency New Zealand and lay bystanders, may also treat shockable rhythms using automated external defibrillators (AED).

Analysis of the New Zealand registry for all OHCA cases reveals that survival at 30-days post-arrest is 28% when the presenting rhythm is shockable compared with survival for PEA of 7% and < 1% for asystole. For patients who have witnessed cardiac arrest with a shockable rhythm, the 30-day survival rate is 32%, contrasting with 7% for PEA cases (Dicker, Todd, et al., 2021). The Resuscitation Outcomes Consortium (ROC) of North America shows the epidemiological patterns of the first rhythm presentation PEA is increasing from 20.3% in 2006 to 21.8% in 2010, resulting in a 1.5% increase (Daya et al., 2015). The reduction in shockable cardiac arrest rhythms may be attributed to increased use of cardiac medications such as beta-blocker therapy and cardiac depressant medication

[3] Paramedic – The term paramedic for this research refers to all practice levels of emergency medical technician, paramedic, intensive care paramedic and critical care paramedic.

(Myerburg et al., 2013). Insertion of implantable cardioverter defibrillator (ICD) has also increased in recent years (Mond & Crozier, 2019).

Pulseless electrical activity occurs when the heart's electrical impulse, responsible for simulating a cardiac contraction (heartbeat), generates a rhythm displayed on an ECG monitor, but the heart does not contract. This decrease in cardiac contractility is often due to disease processes that reduce preload (heart stretch), increase afterload (pressure which the heart contracts against), or cause respiratory failure (Oliver et al., 2020). This disconnect between electrical stimulation and lack of cardiac contraction is termed 'true PEA' (Labovitz et al., 2010). The determination of this condition during cardiac arrest resuscitation is through a manual 'pulse check' to determine the presence of true pulselessness. The pulse check is performed during a 10 second pause in chest compressions and aims to detect the absence or presence of an underlying heartbeat. However, there is concern regarding the rescuer's ability to palpate the patient's pulse, and the literature suggests that the palpation of a pulse during cardiac arrest may not be accurate (Zengin et al., 2018). This uncertainty can lead to a failure to diagnose profoundly shocked but perfusing states, leading to erroneous management with unnecessary and asynchronous chest compressions and potential high-dose vasopressor drug administration (Badra et al., 2019). As a result, the patient in pseudo-PEA may be prematurely declared dead.

On the other hand, patients in PEA with cardiac activity identified on ultrasound (ultrasound-identified pseudo-PEA) were associated with the return of spontaneous circulation (ROSC) (Masoumi et al., 2021). The authors reported that 62 cases of PEA identified using ultrasound showed 53.2% (n = 33) had mechanical cardiac activity and were identified as pseudo-PEA. Of these pseudo-PEA cases, 63.6% achieved ROSC.

Differences in pseudo-PEA rates identified by ultrasound, ranging from 19% to 75% across various studies, can be attributed to several factors. Higher percentages, towards the 75% mark, are often seen in studies involving early ultrasound application by in-hospital doctors, with patient co-morbidities and critical illnesses increasing the likelihood of PEA cardiac arrest (Breitkreutz et al., 2010; Chardoli et al., 2012; Flato et al., 2015; Gaspari et al., 2017; Gaspari et al., 2016; Masoumi et al., 2021; Prosen et al., 2010; Salen et al., 2005; Zengin et al., 2016). Conversely, studies reporting lower rates, between 19% and 54%, often included out-of-hospital patients, potentially with delayed resuscitations and bystander CPR (Gaspari et al., 2016; Jaramillo et al., 2020; Prosen et al., 2010; Salen et al., 2005).

The New Zealand National Ambulance treatment guidelines for OHCA-PEA include airway management, HP-CPR, adrenaline administration, assessment for reversible causes and manual palpation of the pulse every 2 minutes during the 10 second pulse check pause (National Ambulance Sector Clinical Working Group, 2019). Paramedics can correct two of the 10 established reversible causes of PEA cardiac arrest. These include reversing hypoxia (low oxygen levels) through oxygenation and sodium chloride 0.9% fluid administration for hypotension (low blood pressure). Many reversible causes of cardiac arrest are not recognisable prehospital without the use of ultrasound (Australian Resuscitation Council & New Zealand Resuscitation Council, 2016). Ultrasound can identify causes of profound shock such as tension pneumothorax, pulmonary embolism, and cardiac tamponade (Blanco & Martinez Buendia, 2017). In a potentially reversible condition such as cardiac tamponade, the current recommendation prehospital is the urgent transport of the patient to the emergency department (ED) (National Ambulance Sector Clinical Working Group, 2019).

The following section discusses the key concepts of OHCA resuscitation with a focus on examining the limitations in identifying pseudo-PEA in the out-of-hospital setting.

1.1.1 Key Concepts of OHCA Resuscitation

High-Performance Cardiopulmonary Resuscitation. High-performance-CPR is a systematic approach to optimising the elements of resuscitation. These elements focus on a compression rate of 100 to 120 per minute, optimal ventilations, and early defibrillation. The HP-CPR technique enhances the chest compression fraction (CCF), minimising interruptions. The CCF ratio refers to the division of the total time spent performing chest compressions divided by the entire duration of the resuscitation process (Mathew et al., 2022). A CCF ratio of at least 60-80% is recommended by the American Heart Association (AHA) Cardiopulmonary Resuscitation Guideline to maintain coronary perfusion (Panchal et al., 2020). However, maintaining a high CCF is not sufficient; the quality of compressions plays a crucial role. If the compressions are not performed at the appropriate rate and depth, they may be ineffective. The compressions in target (CiT) metric encompasses the proportion of chest compressions conducted at the appropriate rate and depth (Loza-Gomez et al., 2022). The interplay between CCF and CiT underscores the balance required between quantity and quality in cardiac resuscitation. A high CCF ensures that compressions are performed most of the time during a cardiac arrest, but the CiT ensures these compressions are effective. The AHA consensus statement suggested in 2013 to “avoid unnecessary pulse checks” to reduce CPR interruption (Meaney et al., 2013). A large-scale study of 12,928 patients explored the effect of CCF on the survival rates of OHCA patients with non-shockable rhythms. Interestingly, the highest survival rate was observed among those with a CCF of < 40% (Vaillancourt et al., 2020). Of the 3,366 (26%) PEA patients, 154 received < 40% CFF and 575 received 41 to 60% CCF. Return of spontaneous circulation was achieved for 27% of the < 40% CCF group and 23% of the > 41% CCF group, with survival to discharge at 5.2% and 1.8%, respectively. The adjusted odds of survival for patients with a CCF range of 0-40% were estimated to be 2.00 times larger than those for patients with a CCF range of 81-100%

(95% CI [1.16-3.32]). These results suggest patients in PEA cardiac arrest with a low CCF (0-40%) have twice the odds of surviving compared to those with a very high CCF (81-100%). However, Vaillancourt et al. (2020) noted that CCF of > 40% increased ROSC in non-shockable rhythms but didn't necessarily improve survival.

By questioning these concepts, the relevance, and implications of integrating ultrasound into PEA cardiac arrest care are highlighted and discussed further within the Discussion Chapter.

The Manual Pulse Check. Over a decade ago, the AHA changed the CPR guideline to downplay the emphasis on performing manual pulse checks in cardiac arrest (Field et al., 2010). Accurate palpation of a manual pulse during cardiac arrest, even by highly trained health professionals, was shown to be inaccurate. A study by Dick et al. (2000) highlighted an example of pulse check inaccuracy who assessed 206 emergency medical technicians (EMT) and paramedics as they performed pulse checks on patients undergoing a carotid artery bypass graft procedure. Only 1.7% of participants correctly identified a pulse in less than 10 seconds, while a palpable pulse was incorrectly declared in 44.9% of attempts. The reduced emphasis on pulse checks, especially in PEA, poses the risk of overlooking pseudo-PEA patients who might benefit from targeted resuscitation.

In today's clinical environment, low-flow shocked patients may go under-recognised with no alternative to the traditional pulse check. However, moving away from this pulse detection method, $ETCO_2$ measurement has emerged as a more reliable marker of ROSC, enhancing the efficiency of cardiac arrest care (National Ambulance Sector Clinical Working Group, 2019).

End Tidal Carbon Dioxide Measurement. This is used routinely within the New Zealand ambulance services to verify correct endotracheal intubation and measure cardiac

output. In cardiac arrest, cardiac output is measured through pulmonary blood flow, which is determined by the quality and quantity of CPR and ventilation strategy. A sampling device measures concentrations of $ETCO_2$ from an advanced airway, such as an endotracheal tube. Outputs provide a measurable physiologic index of resuscitative efforts. The interpretation of $ETCO_2$ is called capnography. Capnography produces a waveform which is displayed on the resuscitation monitor. During CPR, capnography measurements determine the response to resuscitative efforts and ROSC (Aminiahidashti et al., 2018). The use of $ETCO_2$ is recommended by the AHA 2010 to guide resuscitative efforts. Sustained or sudden increases in $ETCO_2$ also indicate ROSC (Meaney et al., 2013).

Accurate $ETCO_2$ levels hinge on factors like CPR quality, underlying conditions, notably pulmonary embolism (PE), and ventilation rate. A PE during cardiac arrest can decrease $ETCO_2$ measurements due to diminished pulmonary perfusion (Aminiahidashti et al., 2018). Whilst experienced ultrasound users might detect PE using ultrasound, such specificity exceeds this research's aims and the typical paramedic's scope for cardiac arrest. However, identifying a clot in transit from a PE can suggest treatment modalities, such as thrombolysis, addressing a reversible cardiac arrest cause. Essentially, PE can challenge $ETCO_2$ reliability in assessing low-flow output.

High-performance-CPR can improve $ETCO_2$ measurements, achieving levels of > 20 mmHg, whereas ventilations of > 12 per minute can reduce this measurement. Gutierrez et al. (2022), sought to determine if variations in CPR depth, rate and ventilation influenced $ETCO_2$ evaluating an adult OHCA population. Their results showed a significant association with CPR depth, explaining variation in $ETCO_2$ measurements during cardiac arrest. Paiva et al. (2018), found $ETCO_2$ of > 10 mmHg was linked with higher rates of ROSC and hospital survival, although $ETCO_2$ measurement of < 10 mmHg is not a reason to withhold

resuscitative efforts. The New Zealand National Ambulance Clinical Practice Guideline outlines $ETCO_2$ measurements of < 15 and > 25 mmHg as indicators of poor or more favourable outcomes (National Ambulance Sector Clinical Working Group, 2019). Importantly, Crickmer et al. (2021), determined that 10 mmHg increases in $ETCO_2$ increased the odds of achieving ROSC (OR = 1.7, 95% CI [1.35, 2.24]; p = < 0.001).

In PEA patients, an increase in $ETCO_2$ often indicates ROSC, but this change can be subtle and overlooked. In addition, HP-CPR has demonstrated higher levels of $ETCO_2$ of > 20 mmHg, resulting in uncertainty of ROSC in low-flow states. Additionally, a less discussed form of ROSC detection in PEA is the width of the QRS complex on an ECG.

Electrocardiogram. The ECG is an essential tool utilised in cardiac arrest to differentiate between rhythms. Historically, associations with QRS width and ECG complex size in PEA distinguished between true and pseudo-PEA. A study by Bergum et al. (2016), investigated the association between PEA ECG patterns and underlying causes of cardiac arrest. Their results showed that the majority (90%) of QRS complexes were widened, and a further 63% exhibited bradycardia (< 60 beats per minute); they concluded that ECG patterns weren't predictive of survival. In contrast, Skjeflo et al. (2018), found a correlation between increased heart rate and concurrent narrowing of the QRS complex appearing 3 to 6 minutes before ROSC. The QRS width may have limitations, and monitoring heart rate increases is an easier predictor of ROSC in PEA situations.

Whilst the manual pulse check, $ETCO_2$, and ECG analysis are not the focus of this research, it is essential to recognise the limitation of current practices in detecting and considering reversible causes of PEA cardiac arrest. This acknowledgement presents an opportunity to use ultrasound as an assessment tool to improve management decisions, potentially enhancing pseudo-PEA cardiac arrest recognition.

1.1.2 What is Ultrasound

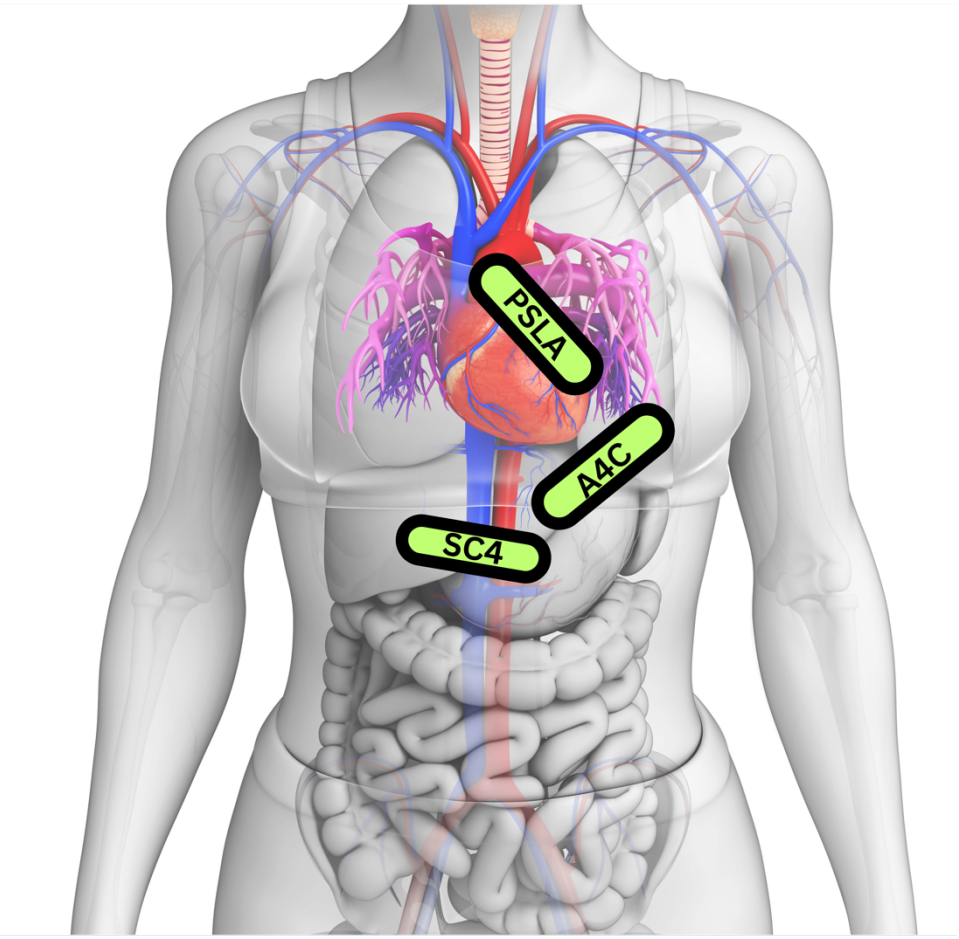
Ultrasound is a frequency of sound greater than 20,000 Hertz (Hz) not audible by the human ear. In diagnostic ultrasound, sound waves (acoustic waves) pulse through a tissue medium, reflecting off structures in the body where they are processed into an image (Edelman, 2007). There are three types of transducers used in the out-of-hospital setting including the linear, curvilinear and the phased array. The linear is a high frequency transducer used for imaging shallow structures such as the lung pleura, blood vessels and nerves. The curvilinear is a lower frequency typically used for imaging deeper structures such as those in the abdomen. The phased array transducer has a low to medium frequency range allowing for higher tissue penetration and improved frame rate to capture moving structures such as the heart (Soni et al., 2020). The phased array transducer was used in this study.

1.1.3 Echocardiographic Views

The four main echocardiographic views used in prehospital ultrasound include the parasternal long axis (PSLA), parasternal short axis (PSA), apical four-chamber (A4C) and the subcostal four chamber view (SC4) shown in Figure 1. For the purposes of this study the PSA view was not integrated into the exam protocol due to the difficulty of acquisition.

Figure 1

Echocardiography Views

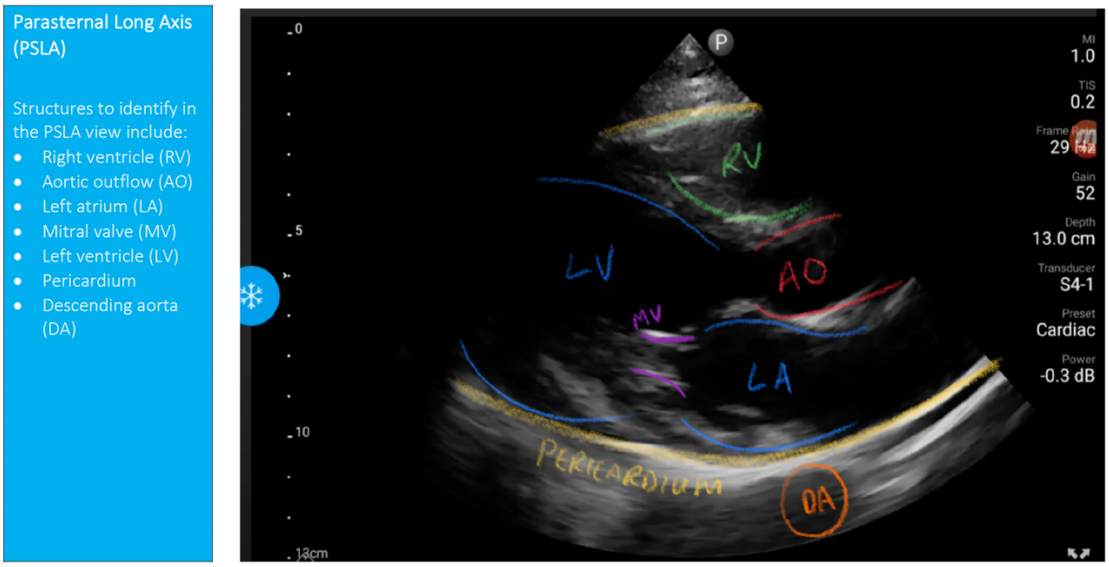


Note. Image created by the author using Canva.com (paid version). PSLA = parasternal long axis, A4C = apical four chamber and SC4 = subcostal chamber four.

The PSLA ultrasound view shown in Figure 2 is imaged by placing the transducer adjacent to the left of the sternum over the third or fourth intercostal space with the transducer orientation marker to the patient's right shoulder (Soni et al., 2020). Key structures identified in the PSLA view include the right ventricle (RV), aortic outflow (AO), left atrium (LA), mitral valve (MV), left ventricle (LV), pericardium and descending aorta (DA).

Figure 2

Parasternal Long Axis Ultrasound Image

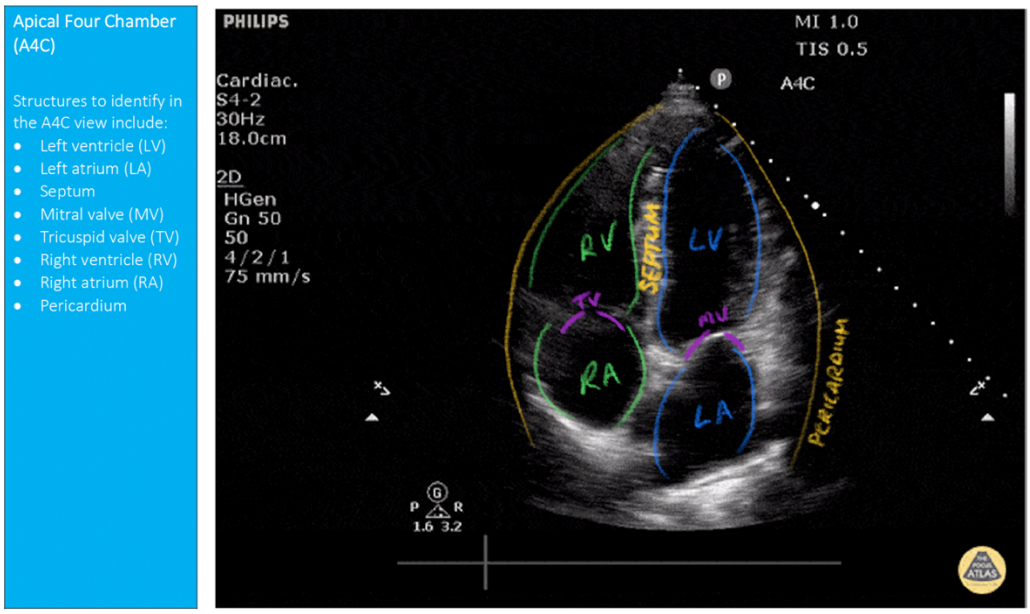


Note. Ultrasound Image and information created by the author and included in the education package for this research.

The A4C ultrasound view shown in Figure 3 is ideally imaged with the patient in the left decubitus position (laying on their left side) however in cardiac arrest the patient is positioned supine. The transducer is placed in the apical window below the left nipple for males and in the lower lateral quadrant of the left breast for females. Alternatively, the transducer can be placed in the fifth intercostal space towards the apex of the heart. The ultrasound beam is tilted towards the patient's right shoulder with the transducer orientated towards the patients left axilla (Soni et al., 2020). Key structures identified in the A4C view include the LV, RV, LA, RA, mitral valve, tricuspid valve, pericardium and septum.

Figure 3

Apical Four Chamber View Ultrasound Image

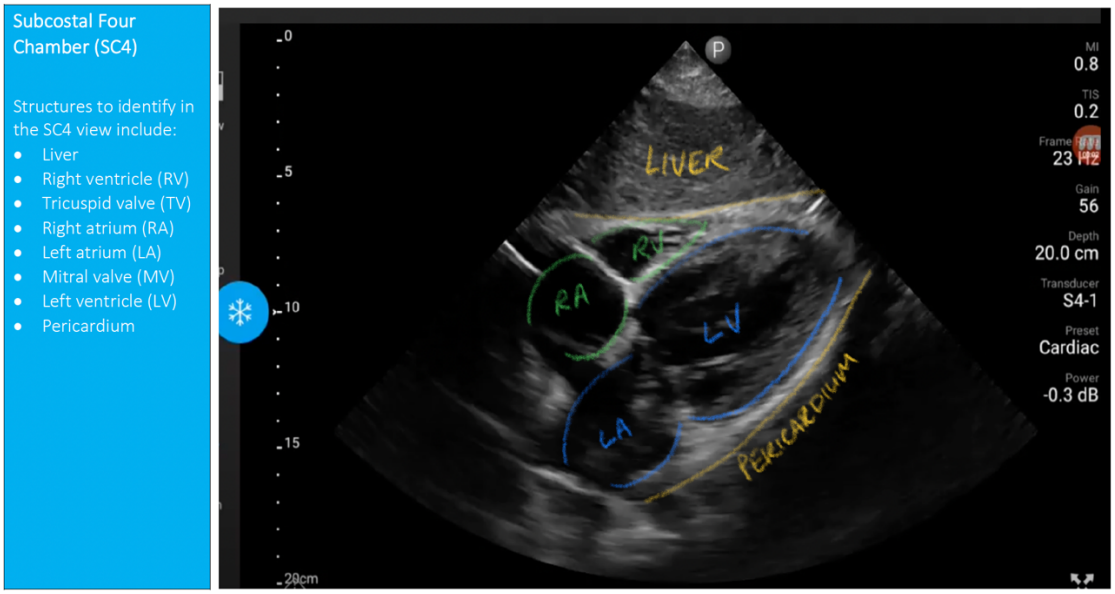


Note. Ultrasound Image https://www.thepocusatlas.com/echocardiography-2 by Justin Bowra MBBS, FACEM, CCPU Emergency Physician. Anatomical structural highlights superimposed by the author and included in the education package for this research.

The SC4 ultrasound view shown in Figure 4 is favourable in critically unwell patients because the subcostal region is easily accessible, especially during cardiac arrest when CPR is performed, and defibrillation pads and CPR feedback sensors are in place. The transducer is placed below the xiphoid process using the liver as the acoustic window, positioning the probe indicator to the right and aiming the ultrasound beam towards the patient's left shoulder (Diaz-Gomez et al., 2021). Key structures include the pericardium, RV, LV, LA and LA.

Figure 4

Subcostal Four Chamber Ultrasound Image



Note. Ultrasound Image and information created by the author and included in the education package for this research.

1.2 Statement of the Problem

The progression of modern medicine has changed the spectrum and survivability of cardiac arrest, with increases in the presentation of PEA (Chardoli et al., 2012; Oliver et al., 2020). However, survival from PEA remains low and it is underrepresented in research. The past 60 years have shown significant progress and improved survival from cardiac arrest. Extensive research has been conducted on the survivability of VF arrest, leading to substantial improvements such as practical training programs and increased public awareness. These advancements also include broad access to public defibrillators and innovations like the GoodSAM first responder program (Parish et al., 2003; Smith et al., 2022). Despite overall advancements in cardiac arrest survival, the challenge is to enhance PEA survival

through improved recognition and informed treatment decisions for low-flow shocked pseudo-PEA states. The PEA patient presents with a complex condition that is not easily identified in the out-of-hospital setting using current treatment methods to identify the underlying cause (Van den Bempt et al., 2020). The early identification of reversible causes in PEA is vital to optimise focused treatment and improve survival. For example, a multicentre study of 793 hospital PEA cardiac arrest patients demonstrated that 54.9% (*n* = 225 of 414) had cardiac activity on ultrasound. Of the 793 patients, 34 had a pericardial effusion, and 13 required a pericardiocentesis procedure, of which 15.4% survived hospital discharge (Gaspari et al., 2016).

The 2022 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations highlights weak recommendations and low-certainty evidence for ultrasound use in cardiac arrest. Ultrasound is advised for experienced clinicians without interrupting CPR, especially when a reversible cause is suspected. The balance between CPR interruption risks and ultrasound benefits is emphasised, with concerns about its diagnostic value, clinical context, and selection bias. Knowledge gaps include point of care ultrasound (POCUS) diagnostic accuracy during cardiac arrest, uniform terminology, reviewer reliability, feasibility during CPR, and impact on outcomes (Wyckoff et al., 2022).

1.3 Ultrasound Paramedic Practice in New Zealand

The author has observed limited uptake of ultrasound in the out-of-hospital setting in New Zealand. A crucial aspect of this Doctoral research involves advocating for practice change. The author established and facilitated the postgraduate ultrasound imaging course for paramedics at Auckland University of Technology (AUT). This course is specifically tailored for prehospital providers to gain knowledge and proficiency in POCUS. The development of

the ultrasound course is supported by New Zealand's two ambulance organisations, Hato Hone St John Ambulance and Wellington Free Ambulance. Hato Hone St John Ambulance is planning a New Zealand-wide trial for extended care paramedics to use ultrasound in low acuity patients. Furthermore, in November 2022, WFA embraced a pilot ultrasound project proposed and led by the author. At the time of writing, this project is underway with training and equipment for five critical care flight paramedics to utilise ultrasound within their clinical practice. Chapter six builds on this discussion with the presentation of a proposal to introduce a Certificate of Prehospital Performed Ultrasound (CPPU) for the regulation and credentialing of paramedics to perform ultrasound in New Zealand.

These initiatives reflect a significant advancement in the integration of ultrasound in prehospital care in New Zealand. The goal of providing comprehensive training and facilitating access to ultrasound technology is to enhance diagnostic capabilities and ultimately improve patient care in the prehospital setting.

1.4 Research Aims

This research aims to examine and address the gaps within the literature. This research seeks to determine relationships and patterns by asking the following questions and providing evidence and insight to inform clinical practice and identifying where further research may be required. The research involved three phases. Phase I includes an online pre-education module, phase II didactic and hands-on training, simulation assessments and knowledge testing and phase III assessments and knowledge testing only.

1.4.1 Research Question One: Image Acquisition

Can 100% of paramedics who receive cardiac arrest-focused echo (CAFE) education and training acquire ultrasound images within the 10 second pulse check pause at simulated

cardiac arrests at least 90% of the time? The CAFE exam is discussed in detail in CAFE Exam Interpretation.

1.4.2 Research Question Two: Quality of Imaging

Can 100% of CAFE trained paramedics achieve a Cardiac Ultrasound Structural Assessment Scale (CUSAS) score of ≥ 3 in at least 90% of simulated cardiac arrest echo attempts?

1.4.3 Research Question Three: Image Interpretation

Can 100% of CAFE trained paramedics accurately identify the presence or absence of pericardial effusion, pseudo-PEA, true PEA, left ventricular contraction and valvular movement as measured by the CAFE exam fluid and function assessment analysis in ≥ 90% of cases?

1.4.4 Research Question Four: Underpinning Knowledge

Can 100% of CAFE trained paramedics achieve a pass mark of ≥ 80% on the quiz testing foundational knowledge and correctly diagnose the presence of cardiac tamponade?

1.4.5 Research Originality

This research is the first out-of-hospital study evaluating ultrasound use in PEA cardiac arrest within New Zealand. The simulation-based approach provides a controlled environment to collect data and demonstrate practical implications. This research may contribute to the literature and knowledge exploring ultrasound use in out-of-hospital PEA cardiac arrest.

1.5 Ambulance Services in New Zealand

The New Zealand Government oversees multiple organisations in the out-of-hospital sector. The Ambulance Team provides strategic leadership commissioning emergency ambulance services, on behalf of Te Whatu Ora Health New Zealand, and the Accident Compensation Corporation (ACC). Their roles include advancing ambulance strategy, addressing Māori health, improving system efficiencies, and fulfilling obligations to meet Te Tiriti o Waitangi (Te Whatu Ora Health New Zealand, 2024).

The two ambulance providers in New Zealand, Hato Hone St John and Wellington Free Ambulance are contracted to deliver out-of-hospital care for medical and traumatic emergencies within the urban and rural communities. Emergency medical services include road-based ambulances, air ambulances (helicopters and planes) and communication centres that receive emergency calls, dispatch ambulances, and provide clinical advice to callers.

1.5.1 Ambulance Strategy

The New Zealand ambulance services follow a professionally autonomous paramedic system based on a paramedic-led model of expertise which has undergone professionalisation, including self-regulation, national registration, and university entry standards for practice. This system is integrated into the local healthcare and public health framework and has devised a service delivery strategy covering emergency, urgent, and primary care models. Both traditional and non-traditional clinical roles are employed in a coordinated approach to service delivery encompassing a paramedic-led model of expertise (Makrides et al., 2022). In contrast, many European ambulance systems follow the ‘Franco-German’ model of predominantly doctor-led ambulances with nurses and/or paramedics (Makrides et al., 2020).

In 2009, the New Zealand Minister of Health identified three strategic ambulance provider goals to be achieved by 2020. These goals included leadership, community resilience and seamless delivery of ambulance services within the wider health sector (National Ambulance Sector Office, 2009). The goal of leadership examined methods of aligning service expectations with patient outcomes. Providers were asked to be accountable for and develop sustainable funding, drive service expectations, and develop performance indicators to achieve this. Community resilience goals included community pride and confidence within the ambulance service. This was achieved through improved sustainability of paid employed and volunteer workforce, alternative service models and integration into the emergency management planning system. The final goal of seamless delivery was patient-focused, improving outcomes and coordinated care. The aims were to improve the level of clinical expertise, develop consistent protocols and extend the role of the paramedic. In addition, a further aim was to develop information sharing, evaluate health outcomes and ensure ambulance response was clinically appropriate for each patient (New Zealand Ambulance Sector Office, 2009).

1.5.2 New Zealand Paramedic Workforce Demographics

Paramedicine in New Zealand has seen a rapid change since the 1970s with the introduction of higher education and expanded clinical practice (Tunnage et al., 2015). In 2020, paramedicine became formally recognised as a profession under the Health Practitioners Competence Assurance Act (HPCAA) 2003. In March 2021 the registration of paramedics opened through Te Kaunihera Manapou[4] Paramedic Council. At the time, there were three pathways to registration:

[4] Te Reo Māori for The Paramedic Council

- Pathway A: recognised a Bachelor of Health Science (BHSc) from AUT or Whitireia and WelTech Community Polytechnic New Zealand.
- Pathway B: recognised existing qualifications and experience, and providers applied for a Registration Assessment Programme.
- Pathway C: provided a process for paramedics in non-clinical positions such as education and research to submit a portfolio of experience evaluated by independent assessors. This pathway was offered for a limited time and has now closed.

To uphold the principles of Te Tiriti[5], all paramedic applicants must complete cultural competencies through Mauirora online learning and other methods, as mandated by the Paramedic Council (Kaunihera Manapou Paramedic Council of New Zealand). The Paramedic Council acts as the regulatory body overseeing the registration of paramedics under The HPCAA 2003. Additionally, the Paramedic Council ensures paramedic competence, issues practising certificates, defines the scope of practice, accredits educational institutions, addresses health and competence issues notifications, and handles complaints about paramedic conduct (Tunnage et al., 2015). Clinical practice for paramedics employed by ambulance providers identify a level of practice which is clearly defined by skills listed at the front of the National Clinical Practice Guidelines (National Ambulance Sector Clinical Working Group, 2019). Registered paramedics use their clinical skills, knowledge and judgement to provide emergency and non-urgent care to patients within the community (Bryne, 2020).

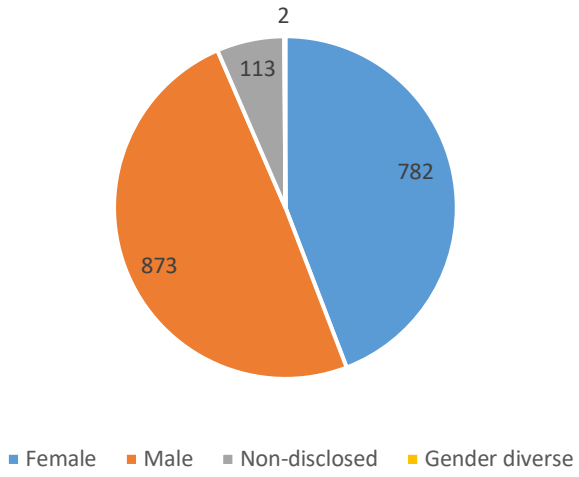
For the purposes of statistical analyses, there are approximately 1,770 registered paramedics in New Zealand at the time of writing. Among these registered paramedics, 873 (49%) identify as male, 782 (44%) as female, 113 (6%) as non-disclosed and two (< 1%) as

[5] Te reo Māori for The Treaty of Waitangi

gender diverse shown in Figure 5 (K.Cook, Paramedic Council, personal communication, 29th July 2022).

Figure 5

Gender of Registered Paramedics in New Zealand 2022

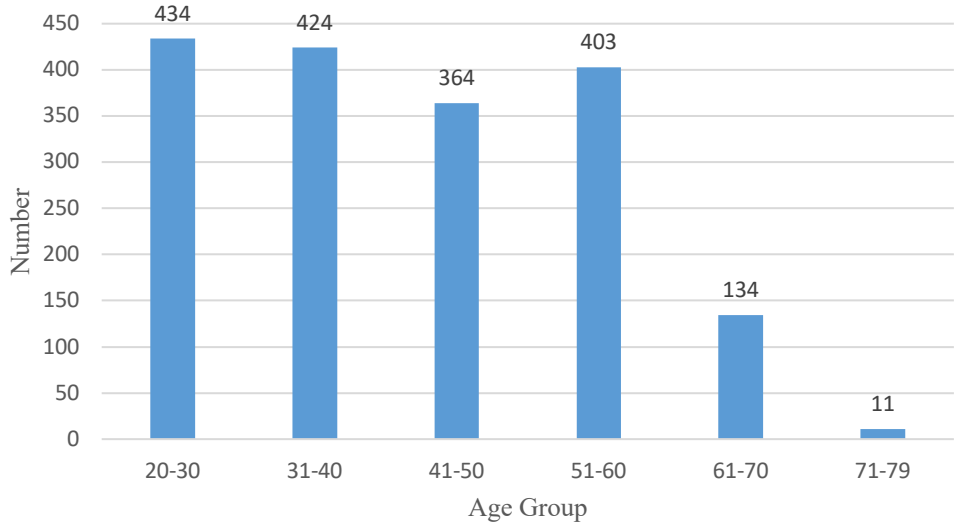


Note. Data provided by K. Cook Paramedic Council 31st March 2022

The age of registered paramedics is categorised into six age groupings, as shown in Figure 6. Of 1,770 paramedics, 434 (24.5%) are aged between 20-30 years, 424 (24.9%) between 31-40 years, 364 (20.5%) between 41-50 years, 403 (22.7%) between 51-60 years, 134 (7%) between 61-70 and 11 (0.06%) between 71-79 years.

Figure 6

New Zealand Registered Paramedics Age Group 2022



Note. Data provided by the New Zealand Paramedic Council on the 31st of March 2022.

According to the Pānui – Hūrae Newsletter in July 2023, it's reported that New Zealand has seen a growth in the number of registered paramedics, with a total of 2,108, marking a rise of 338 compared to the previous year. When broken down by demographics, 44% (or 943) of these registered paramedics identified as female. Additionally, Māori representation stands at 5.8% (or 123 paramedics), while Pacific Peoples make up 1.8% (or 40 paramedics) (Kaunihera Manapou Paramedic Council of New Zealand, 2023b).

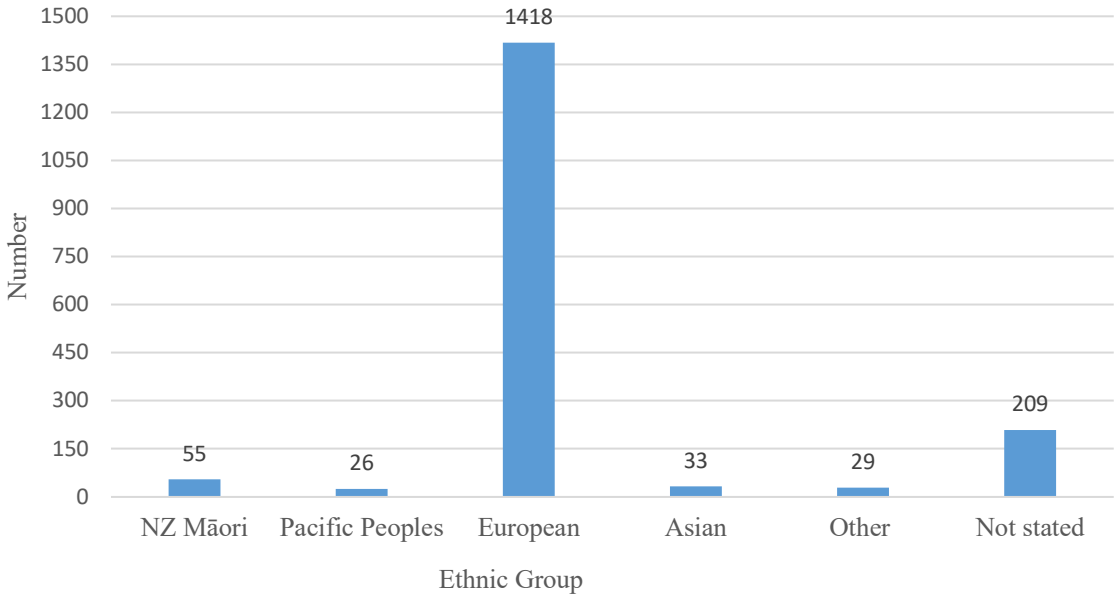
In New Zealand, there is significant under-representation of Māori and Pacific Peoples in the paramedic workforce. Strengthening ethnic engagement and participation within the out-of-hospital setting improves inequities of emergency care (Morrison & Tunnage, 2014). Promotion of research with inclusive representation enriches the study design by bringing diverse perspectives, cultural insights, and enhanced community

engagement. This approach is pivotal for fostering inclusivity and addressing health disparities among marginalized groups within the research in general.

This research used the level one ethnic group New Zealand Statistics reporting standards. The six ethnic groupings are Māori, Pacific peoples, Asian, MELAA (Middle Eastern, Latin American and African), European and Pākehā, and other ethnicities (Ministry of Health, 2017). Ethnicity data from the New Zealand Paramedic Council included 48 ethnic subgroups for 1,770 paramedic responses. The author merged these groups using the ethnic grouping standards set by Statistics New Zealand for census data collection (https://www.stats.govt.nz/tools/2018-census-ethnic-group-summaries) to allow statistical analyses. Most paramedics identify as European, New Zealand European or New Zealander (*n* =1,418, 80%), with less representation from Māori (55, 3%) and Pacific Peoples (26, 1%), Asian (33, 2%) and other (29, 2%) shown in Figure 7. Of the population, 209 (11%) respondents did not state or declare their ethnicity.

Figure 7

New Zealand Registered Paramedic Ethnicity 2022



Note. Data provided by the New Zealand Paramedic Council, transposed by the author into five ethnic groupings (n=1770).

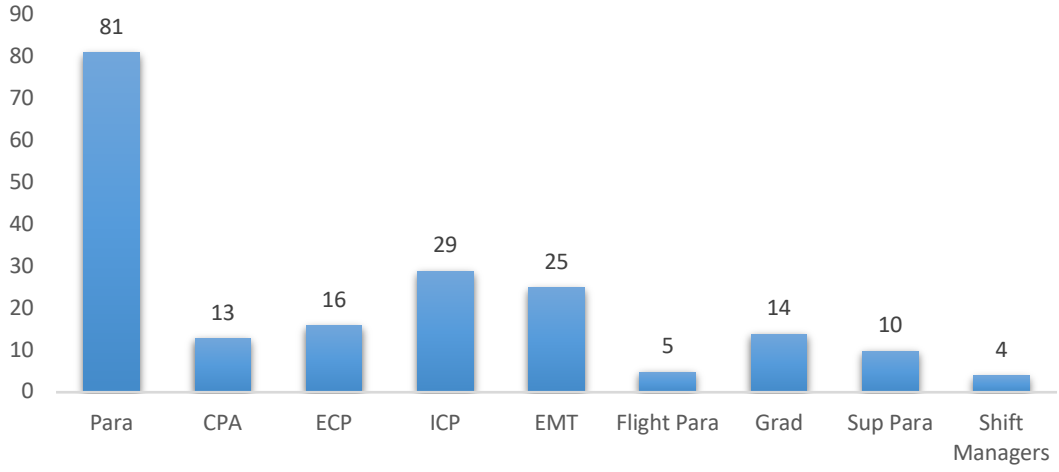
The paramedic workforce is stratified into four main tiers: unregistered emergency medical technician (EMT), registered paramedic, extended care paramedic (ECP) and critical care paramedic (CCP). Additional scopes of practice include clinical practice advisors (CPA) and flight paramedics. In addition to these existing designations, the Paramedic Council has recommended adding ECP and CCP designations as specialist paramedic practices. This proposed endorsement is designed to acknowledge paramedics with advanced qualifications and expertise (Kaunihera Manapou Paramedic Council of New Zealand, 2023a).

1.5.3 Wellington Free Ambulance Paramedic Workforce

At the time of writing, the WFA had 197 frontline emergency ambulance personnel with level of practice, as shown in Figure 8. Of these, 81 were at the paramedic level, with 29 ICPs and five flight paramedics. Other roles within WFA included ECP (also paramedic level with a specific additional range of practice), EMT, graduate paramedic (first-year post-university graduation), supervised paramedic (second year of employment) and Shift Managers who align with a shift to provide managerial and on-road support to the crew.

Figure 8

Wellington Free Ambulance Level of Practice 2022



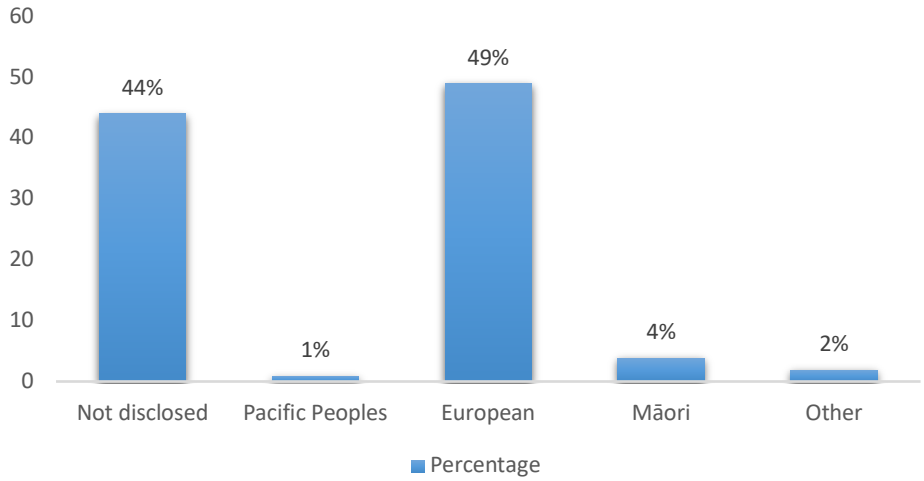
Note. Para = paramedic, CPA = clinical paramedic Advisor, ECP = extended care paramedic, ICP = intensive care paramedic, EMT = emergency medical technician, Flight Para = flight paramedic, Grad = graduate, sup Para = supervised paramedic.

Ethnicity data collection within WFA is inaccurate, as 44% of frontline personnel did not respond to the workplace demographic survey. From the available data in 2020, WFA

staff identified as 49% European, 4% Māori, 1% Pacific Peoples and 2% other, as shown in Figure 9.

Figure 9

Ethnicity of Wellington Free Ambulance Workplace Demographic Survey 2020



Note. Information was provided by WFA Human Resources Manager Chris Wright by email correspondence 5th of July 2020.

1.5.4 New Zealand Geography and Population

New Zealand is a small island country in the southwest ocean. New Zealand has a similar land mass to the United Kingdom, spanning 1,600 km long and approximately 450 km at the wides point (Blyth et al., 2024). The diverse population of New Zealand is approximately 5 million, with an Māori population estimated at 775,836 (Statistics New Zealand, 2020). The population density of New Zealand is 15 people per km^2 compared to the

United Kingdom's 243 people per km^2. Geospatial modelling has the majority (86%) of New Zealand inhabitants living in an urban region (Lilley et al., 2019). The geographical nature of New Zealand is challenging, with mountainous ranges, volcanos, steep hills, and fjords. This varied terrain emphasises the importance of suitable ambulance response measures for time-critical patients suffering an OHCA. These geographical and demographical considerations provide insight into the understanding and challenges associated with the broad and diverse landscape within the context of cardiac arrest care in New Zealand. A map of the world highlighting New Zealand's location is shown in Figure 10 encircled in red.

Figure 10

Map of the World



Note. Standard Licence Free Image - The Earth, World Map on dark background. Vector illustration by Yan4ik– stock.adobe.com. New Zealand circled in a red outline.

1.5.5 Study Setting

The study was set in the Greater Wellington and Wairarapa regions of New Zealand. At the time of writing, 10 ambulance stations are located throughout the area, as shown in Figure 11. On average, WFA receives over 150,000 emergency calls for approximately 58,000 emergencies annually (Wellington Free Ambulance, 2022). Of these, 209 were for OHCA responses (Dicker, Swain, et al., 2021).

This observational simulation trial was conducted in Wellington utilising paramedics employed by WFA, doctors from the Wellington Emergency Department, international ultrasound experts for ultrasound scan reviews and support staff from WFA and AUT.

Figure 11

Wellington Free Ambulance Region



Note. Reproduced from https://www.wfa.org.nz/about-us/our-region/

1.6 Thesis Structure

This thesis comprises six chapters detailing research conducted with the Wellington Free Ambulance, serving the Greater Wellington and Wairarapa areas of New Zealand. The research presents an educational model and simulation techniques to incorporate POCUS in

advanced cardiac arrest care, adhering to the Australia and New Zealand Council of Resuscitation (ANZCOR) standard of a 10 second or less no-flow hands-off time (HOT) during pulse checks. Chapter summaries include:

1. Chapter One: Introduces background themes relevant to the 10 second pulse check pause and pseudo-PEA determination and explores the New Zealand setting.
2. Chapter Two: Presents literature reviews focusing on OHCA-PEA and the education surrounding out-of-hospital ultrasound.
3. Chapter Three: Describes the research methodology, detailing the educational programme, the design of phases I, II, and III, and the methods for data collection and measurement.
4. Chapter Four: Delves into the results, highlighting characteristics of the study participants and the investigations into individual research questions.
5. Chapter Five: Is a comprehensive discussion, outlining key findings, identifying the study's strengths and limitations, and offering practical recommendations. Chapter five also showcases the transformative impact of introducing ultrasound to ambulance services in New Zealand, underscoring the importance of this research opportunity for out-of-hospital ultrasound in the country.
6. Chapter Six: Provides a conclusion, summarising the research findings and integrating the content of the thesis.

Chapter 2 Literature Review

2.1 Out of Hospital Cardiac Arrest Pulseless Electrical Activity

The previous chapter introduced OHCA arrest in New Zealand, specifically PEA, and the tools currently used by the ambulance service to determine the return of spontaneous circulation. This literature search and review was completed by the author examining published literature seeking to identify what has been accomplished to build on previous work and identify gaps (Grant & Booth, 2009). The review centres on journal articles and references from the selected articles.

2.1.1 Method of the Literature Review

The review was undertaken using a narrative approach analysing the contribution or value for inclusion within the review. The electronic databases CINAHL complete, SCOPUS, PubMed via EBSCO and Web of Science were searched from 21st April to 26th April 2021. For currency, only full-text articles published from 2005 to 2021 were included in this review. The exclusion of articles prior to 2005 was due to the relatively new use of ultrasound in the prehospital setting. Key words and phrases used for the literature search are shown Table 1 including point of care ultrasound or POCUS or echo* or AND cardiac arrest or heart arrest or cardiopulmonary arrest AND or OHCA or prehospital or prehospital or paramed* or EMS or emergency medical service or ambulance or EMT or emergency medical technician AND pulseless electrical activity or PEA.

Table 1

Literature Review Search Terms

Line	Search term	Theme
1	"point of care ultrasound" or POCUS or echo* or "focused echo*"	Ultrasound
2	"cardiac arrest" or "heart arrest" or "cardiopulmonary arrest"	Cardiac arrest
3	"out of hospital cardiac arrest" or OHCA or prehospital or pre-hospital or paramed* or EMS or "emergency medical service" or ambulance or EMT or "emergency medical technician"	EMS
4	"pulseless electrical activity" or PEA	PEA

Note. " " = search phrase, * = any ending

The inclusion criteria were studies examining the use of ultrasound in (a) cardiac arrest and (b) prehospital PEA. Articles reviewed were entered into a review matrix and scaled according to their relevance from one to four: One is irrelevant, two borderline, three relevant and four important. Abstracts, editorials, reports, and letters were excluded due to insufficient data. A summary of literature reviewed is shown in Table 2. The literature identified for inclusion or exclusion is shown using a Preferred Reporting Items Systematic Reviews and Meta-Analysis (PRISMA) flow diagram shown in Appendix E. The review identified several potential issues with ultrasound use in cardiac arrest. The following sections will review ultrasound use in OHCA-PEA, the 10 second pulse check pause in PEA, and ultrasound image acquisition and interpretation.

The review process identified various studies from different regions demonstrating global interest in using ultrasound in cardiac arrest settings. Seven studies were conducted in the United States of America (Chin et al., 2013; Fitzgibbon et al., 2018; Gardner et al., 2018;

Huis in ’t Veld et al., 2017; Rooney et al., 2016; Salen et al., 2005; Walker, 2017), two from Canada (Gaspari et al., 2017; Gaspari et al., 2016) one from Brazil (Flato et al., 2015) and one from Iran (Chardoli et al., 2012) (Table 2). Furthermore, seventeen studies were conducted in European countries including Germany (Breitkreutz et al., 2010; Breitkreutz et al., 2009; Breitkreutz et al., 2007; Nelson & Sanghvi, 2016; Scharonow & Weilbach, 2018), Norway (Busch, 2006), Denmark and Austria (Aagaard et al., 2018; Aichinger et al., 2012), the United Kingdom (Booth et al., 2015; Hayhurst et al., 2011; Niendorff et al., 2005; Price, Uddin, et al., 2010; Testa et al., 2010; Walker, 2017; Younger et al., 2016), Turkey (Zengin et al., 2016), Italy (Testa et al., 2010), the Netherlands (Ketelaars et al., 2018), Slovenia (Prosen et al., 2010) and Denmark (Aagaard et al., 2018). Eight studies were specifically in the prehospital setting, with ultrasound used during resuscitation in the prehospital setting included. Five studies involved paramedic cohorts (Booth et al., 2015; Chin et al., 2013; Reed et al., 2017; Rooney et al., 2016; Younger et al., 2016). Of these, the majority were prospective, retrospective, or observational reviews.

The following section evaluates the specific findings relating to ultrasound in PEA cardiac arrest.

Table 2

Summary of Papers Reviewed

Author	Title	Location	Study Design	*n*	Main Theme	Evaluation 1-4
Aichinger, G., 2012	Cardiac Movement Identified on Prehospital Echocardiography Predicts Outcome in Cardiac Arrest Patients	Austria	Prospective observational study	42	Cardiac movement observed during initial echo was significantly associated with higher survival rates, supporting the feasibility and utility of focused echo in evaluating outcomes during prehospital CPR	2
Breitkreutz, R., 2009	Focused Echocardiography in Life Support: The Subcostal Window	Germany	Descriptive analysis	-	Feasibility of adding the subcostal window to critical care beyond the FAST	2
Busch. M., 2006	Portable ultrasound in prehospital emergencies: a feasibility study	Norway	Prospective observational study	38	The focused protocol is feasible and beneficial without causing delays in patient care; additional research is needed to clarify its precise indications and role in prehospital settings	2
Aagaard, R., 2018	Timing of Focused Cardiac Ultrasound during advanced life support - A prospective clinical study	Denmark	Prospective clinical study	60	Images obtained during rhythm analysis and bag-mask ventilations were of higher quality compared to images obtained during chest compressions	2
Breitkreutz, R., 2010	Focused echocardiography in life support and peri-resuscitation of emergency patients: A prospective trial	Germany	Prospective observational study	230	Echo performed by an emergency physician as per FEELS protocol	4
*Gardner, K., 2018	The Cardiac Arrest Sonographic Assessment (CASA) exam - A Standardised approach to the use of ultrasound in PEA	United States of America	Abstract	-	Determination of reversible causes using a POCUS	3

Gaspari, R., 2016	Emergency department point-of-care ultrasound in out-of-hospital and in-ED cardiac arrest	Canada	Focused echo evaluation	793	Ultrasound was performed at the beginning of advanced cardiovascular life support (ACLS) and at the end. The primary outcome was survival to hospital admission. Secondary included survival to hospital discharge and ROSC. They used multivariate regression modelling. 20 cites	4
Gaspari, R., 2017	A retrospective study of pulseless electrical activity bedside ultrasound identified interventions during resuscitation associated with improved survival to hospital admission. A REASON Study.	Canada	Multicentre Prospective Observational Study	225	Bedside echo to categorise PEA arrest and ROSC	4
Niendorff, D., 2017	Rapid Cardiac Ultrasound of Inpatients suffering PEA arrest performed by non-expert sonographers.	United Kingdom	Feasibility study	13	Non-expert physicians lead echo subcostal to diagnose tamponade, PE, hypovolemia and lack of cardiac activity	2
Miesemer, B., 2017	Using Ultrasound for Cardiac arrest - second in a three-part series	-	Report	-	-	1
Chin, J., 2013	A pilot study examining the viability of prehospital assessment with the ultrasound for emergencies (PAUSE) protocol	United States of America	Prospective educational intervention pilot	20	Education arm - Enrolled 20 EMT paramedics with no prior ultrasound training. Subjects were tested on interpretation and image acquisition. Two emergency physician images for accuracy. Image interpretation was performed using pre-obtained ultrasound clips containing normal and abnormal images	3

Rooney, K.., 2016	Prehospital assessment with ultrasound in emergencies: implementation in the field	United States of America	Prospective Interventional Educational Study	17	Enrolled and trained 20 paramedics based on PAUSE protocol. Education is 3 hrs, with a 2-hrs didactic portion that includes physics images and machine functions. Plus, base image interpretation. 1 hr of hands-on with healthy models demonstrate SC4, A4C & PSLA	3
Reed, M., 2017	Introduction of paramedic-led echo in life support into the prehospital environment: The PUCA study	United Kingdom	Retrospective review	45	Trained rapid response paramedics were performing ultrasounds during cardiac arrest. Images were reviewed with body camera footage	4
Booth, K., 2015	Training paramedics in focussed echo in life support.	United Kingdom	Prospective pilot observational study	9	The data collected during a 1-day course training 11 paramedics	3
Hayhurst, C., 2010	An evaluation of echo in life support (ELS): is it feasible? What does it add?	United Kingdom	Convenience sample retrospective analysis	56	Ultrasound scanners were doctors or specialist trainees who held level 1 emergency ultrasound competency. A revision session was held, and two centres were included. Scanning was permitted during the 10 second pulse check	3
Zengin, S., 2016	Benefits of cardiac sonography performed by non-expert sonographer in patients with non-traumatic CA	Turkey	Prospective observational study	264	Emergency physicians were dedicated to echo-only resuscitation	3
Walker, E., 2017	Ultrasound: A potential new approach for cardiac arrest management.	United Kingdom	Literature review		Reviewing a new approach to cardiac arrest management	2

Testa, A., 2010	The proposal of an integrated ultrasonographic approach into the ALS algorithm for cardiac arrest: the PEA protocol	Italy	Descriptive analysis and protocol creation	-	Proposed simplified ultrasound protocol for PEA	2
Price, S., 2010	Echocardiography in Cardiac Arrest	United Kingdom	Review	-	To discuss the potential for an echo to aid diagnosis and treatment during resuscitation	2
Scharonow, M., 2018	Prehospital point of care emergency ultrasound: a cohort study	Germany	Prospective observational study	99	Documented all prehospital missions performed by rescue physicians. The findings were compared prehospital with in-hospital ultrasounds performed by rural rescue physicians, who had special training in emergency ultrasound and supervision each month	1
Breitkreutz, R., 2007	Focused echocardiographic evaluation in resuscitation management: Concept of advanced life support - confirmed algorithm	Germany	Multicentre, non-randomised, prospective, protocol-driven observational study	-	Algorithm review	4
Younger, P., 016	Can paramedics perform and evaluate a focused echo during a simulated 10 second pulse check after a 1-day training course	United Kingdom	Observational education study	10	Paramedics were invited to attend a 1-day training, 6 hrs broken into 3 hrs class 3 hrs didactic views SC4/PSLA	3
Flato, U., 2015	Echocardiography for prognostication during the resuscitation of ICU patient with non-shockable rhythm cardiac arrest	Brazil	Multicentre, non-randomised, prospective, protocol-driven observational study	49	Two specialist intensivists with echo level 2/3 performed echo during CPR to the FEEL protocol	4

Ketelaars, R., 2018	Prehospital echocardiography during resuscitation impacts treatment in a physician-staffed helicopter emergency medical service: an observation study	Netherlands	Prospective cohort study	56	Ultrasound was performed after interventions, with the first exam as soon as possible, after every 2 min cycle of compressions, after ROSC, or at the termination of resuscitation	4
Fitzgibbon, J., 2018	Feasibility of OHCA Ultrasound by EMS physicians	United States of America	Observational study	56	EMS residents/fellows responded alongside EMS to OHCA. The training was part of their normal training. Intro package of how to integrate into ACLS	4
Chardoli, M., 2012	Echo integrated ACLS protocol vs conventional CPR in patients with PEA	Iran	Prospective observational study	100	PEA patients were randomised into two groups. Group A - echo evaluating cardiac activity, RV dilation, LV function, pericardial effusion/tamponade and inferior vena cava size. Group B - normal cardiac arrest care, no echo. The presence or absence of mechanical ventricular activity was recorded, and PEA reversible causes were recorded. ROSC was evaluated in both groups	4
Nelson, B., 2016	Out-of-hospital POCUS: current use models and future direction	Germany	Review article	-	-	1
Prosen, G., 2010	Impact of Modified Treatment in Echocardiographically Confirmed Pseudo-pulseless Electrical Activity in Out-of-hospital Cardiac Arrest Patients with Constant End-tidal Carbon Dioxide Pressure during Compression Pauses	Slovenia	Interventional trial with comparative retrospective analysis	84	Outcomes were compared retrospectively with PEA, which had higher $ETCO_2$ and possibly a low flow state. All ALS where ultrasound was used were accompanied by an emergency physician and an ALS instructor with basic training in focused echo use. Outcome measures were performed using the Utstein style, ROSC in the field, survival at 24hrs, discharge, and cerebral performance categories from 1-5	3

Salen, P., 2005	Does the presence or absence of sonographically identified cardiac activity predict resuscitation outcomes of cardiac arrest patients?	United States of America	Prospective observational study	90	PTs were enrolled prehospital and transferred under resuscitation to the nearest ED where ultrasound occurred every 3-5mins during carotid pulse checks. TTE looking in B-mode for absence or presence of kinetic cardiac activity, presenting cardiac rhythm, presence of ultrasound detected activity, prehospital resus time intervals and ED resus time intervals	2
Huis in ‘t Veld, M., 2017	Ultrasound use during CPR is associated with delays in chest compressions	United States of America	Prospective observational study	23	Resus was recorded. POCUS use was documented and time. A linear mixed-effects model was used to estimate the effect POCUS had on pulse check duration	4

Note. *Gardner, K., 2018 was an abstract only. Searched for the full document and located the full article by Clattenburg, E. J., 2018.

Grading Matrix

1- Irrelevant, promising title but content too distant from the topic

2 - Borderline, somewhat peripheral might be worth including depending on research findings

3 - Relevant, useful background material. Similar to other studies

4 - Important, directly relevant to the topic. Established basis for future research

2.1.2 Use in Cardiac Arrest Pulseless Electrical Activity

Point-of-care ultrasound is commonly used during cardiac arrest management by emergency physicians within the ED and is a recognised practice within the international resuscitation guidelines (Atkinson et al., 2019). Notwithstanding, ultrasound in OHCA is not used routinely by ambulance clinicians. Current out-of-hospital treatment guidelines for non-shockable rhythms of PEA emphasise the importance of HP-CPR and the detection of reversible causes. Many of these causes are not recognisable out-of-hospital without ultrasound (Australian Resuscitation Council & New Zealand Resuscitation Council, 2016). When a potentially reversible cause is identified which cannot be treated out-of-hospital, the current recommendation is urgent transport to the ED (National Ambulance Sector Clinical Working Group, 2019).

Previous investigations of pseudo-PEA have reported rates identified by ultrasound ranging between 19% and 75% (Breitkreutz et al., 2010; Chardoli et al., 2012; Flato et al., 2015; Gaspari et al., 2017; Gaspari et al., 2016; Prosen et al., 2010; Salen et al., 2005; Zengin et al., 2016). The higher rates of identified pseudo-PEA may be attributed to the early application of ultrasound by doctors in the community or at witnessed in-hospital cardiac arrest. The lower rates of identification of 19% to 54% included patients from the out-of-hospital setting with more delayed resuscitation and bystander CPR timeframes (Gaspari et al., 2016; Jaramillo et al., 2020; Prosen et al., 2010; Salen et al., 2005).

The Real-time Evaluation and Assessment Sonography Outcomes Network (REASON) study demonstrated a correlation between myocardial activity and improved ROSC, survival to hospital, and discharge rates. In the REASON study, a multivariate analysis revealed that patients who had organised cardiac activity and were administered an adrenergic infusion had a significantly higher likelihood 8.2 (95% CI 1.8-32.1) of achieving

ROSC compared with patients who did not receive this treatment (Gaspari et al., 2017). The ANZCOR guidelines support using ultrasound in cardiac arrest, providing there are no interruptions to CPR (Australian Resuscitation Council & New Zealand Resuscitation Council, 2016). The role of ultrasound in the OHCA has been described as a valuable tool distinguishing pulselessness from profoundly shocked states in pseudo-PEA (Badra et al., 2019). However, ultrasound is not used routinely for PEA cardiac arrest care.

For the past 15 years, emergency physicians, and more recently, the out-of-hospital sector, have observed, intervened, and reported on using ultrasound in cardiac arrest (Nelson & Sanghvi, 2016). The evidence produced out-of-hospital consists mostly of simulation and observational trials (Booth et al., 2015; Reed et al., 2017; Younger et al., 2016). According to the grading of recommendations assessment, development, and evaluation approach outlined in the Consensus on Cardiopulmonary Resuscitation Emergency Cardiovascular Care Science with Treatment Recommendations (CoSTR), these findings are categorised as presenting low-quality evidence (Australian Resuscitation Council & New Zealand Resuscitation Council, 2016). Several studies within this review integrated ultrasound protocols into existing resuscitation guidelines, focusing on minimising pulse check interruptions, as shown in Table 3.

Table 3

Literature where resuscitation ultrasound was incorporated into the study (by publication date)

Author	Protocol/Study	Purpose	*n*	Clinician Action	Pulse Check Pause
Lien et al., 2018	US-CAB (Ultrasound – Circulation, Airway and Breathing)	To systematically evaluate circulation, airway, and breathing.	177	Emergency department ultrasound assessment of heartbeat, confirmation of tracheal intubation and bilateral lung slide.	Circulation 9.0 seconds (7.6 – 10.4) Airway 7.5 seconds (6.0 – 9.0) Breathing 16.0 seconds (14.9 – 17.9)
Clattenburg, E. J., 2018	CASA Exam (Cardiac Arrest Sonographic Assessment)	Evaluate pre and post intervention- stepwise protocol to assess reversible causes of pulseless electrical activity.	38 pre intervention 45 post intervention 267 cardiac arrest events	Emergency department ultrasound during < 10 second pulse check between resuscitation attempts (2 mins), evaluate for 1) cardiac tamponade 2) right heart strain 3) cardiac activity.	Pre-intervention 19.8 seconds (17.9-21.7) Post-intervention 15.8 seconds (14.4-17.2)
Gaspari, R., 2017	REASON Study	Multicentre Prospective Observational Study.	225	A retrospective study of pulseless electrical activity, bedside ultrasound identified interventions during resuscitation associated with improved survival to hospital admission. A REASON Study.	Pre intervention 28.3 seconds (95% CI [25.1, 31.5]) Post intervention 12.8 seconds (95% CI [11.9, 13.7])
Reed et al., 2017	Paramedic Ultrasound in Cardiac Arrest (PUCA)	Evaluate the heart during the 10 second pulse check.	45	During the 10 second pulse check, paramedics obtained a view and interpreted a 3-second cardiac video clip. Interpretation at the time evaluated heart function and other pathology. Video footage and commentary were recorded.	17 seconds (IQR 13–20)
Lichtenstein & Malbrain, 2015	Sequential Echographic Scanning Assessing Mechanism or Origin of Severe Shock of Indistinct Cause (SESAME Protocol)	A protocol used for profound shock and cardiac arrest.	-	Intensive Care Unit bedside ultrasound in cardiac arrest and profoundly shocked patients, examining the lungs, legs, abdomen, and heart, are evaluated for the cause of hypotension or arrest.	-

Chin et al., 2013	Prehospital Assessment with Ultrasound for Emergencies (PAUSE)	Examining the viability of prehospital assessment with the US for emergencies PAUSE protocol.	16 cardiac views	Emergency medical technicians with no prior ultrasound experience applied a two-step approach evaluating 1) pleural line exam to rule out pneumothorax 2) focused transthoracic echocardiogram to look at heart motion and tamponade. Simulation study focused on image acquisition.	12 Echo views in < 10 seconds (no further data provided). One paramedic took approximately 90 seconds, and the other three ranged between 10 and 25 seconds.
Hayhurst et al., 2010	ELS (Echo in Life Support)	To review the adequacy of views obtained, and timing of the scan and the clinical findings of pericardial effusion and ventricular wall movement.	56	Emergency department ultrasound scan during the 10 second pulse check using one of three echo windows.	45/47 < 0 seconds
Breitkreutz et al., 2010	FEELS (Focused Echocardiographic Evaluation in Life Support)	To evaluate the feasibility of the FEELS protocol applied by trained emergency doctors and report.	-	Diagnose and exclude during the < 10 second pulse check from one of three echo views potentially treatable causes of cardiac arrest.	-
Hernandez et al., 2008	CAUSE (Cardiac Arrest Ultrasound Exam)	A protocol was developed to address the four leading causes of cardiac arrest.	-	Emergency department patients with non-shockable cardiac arrest. Obtain a four-chamber view of the heart to rule out tamponade, hypovolemia, and massive PE. Also, lung slide to rule out pneumothorax.	-
Breitkreutz et al., 2007	FEER (Focused Echocardiographic Evaluation in Resuscitation)	Develop an algorithm and integrate into the cardiac arrest.	-	In hospital protocolised 10-step approach integrating into the resuscitation guideline. An echo was to be obtained within 5 seconds during the pulse check pause ruling out reversible causes.	-

Note. Cardiac arrest protocols were selected from articles within this literature review.

2.1.3 The 10 Second Pulse Check Pause in Pulseless Electrical Activity

More than three decades of literature have demonstrated the healthcare professional's inability to identify a pulse in cardiac arrest (Badra et al., 2019; Eberle et al., 1996). In the presence of PEA and asystole, treatment decisions hinge on the outcome of the pulse check. There is concern regarding the paramedic's ability to detect the patient's pulse, and the literature suggests that the palpation of a pulse during cardiac arrest may not be accurate (Zengin et al., 2018). The ANZCOR guideline highlights the definition of PEA as a co-ordinated electrical rhythm with an impalpable pulse (Australian Resuscitation Council & New Zealand Resuscitation Council, 2016). This uncertainty can lead to a failure to diagnose profoundly shocked but perfusing states, leading to unnecessary asynchronous chest compressions and high-dose vasopressor drug administration (Badra et al., 2019). Diagnosing a profoundly shocked pseudo-PEA state in the presence of a non-palpable pulse may have prognostic importance for this group. The literature suggests that PEA and asystole have different prognoses and represent different entities, requiring a distinctive approach to each (Labovitz et al., 2010). Incorporating ultrasound into the 10 second pulse check pause increases accuracy when evaluating for a low-flow shocked state in real-time.

Adding an ultrasound examination into the cardiac arrest algorithm frequently results in the pulse check exceeding the 10 second limit (Clattenburg, Wroe, Brown, et al., 2018; Reed et al., 2017). This is concerning as delays in CPR worsen patient outcomes (Paradis, 1990). The Paramedic Ultrasound in Cardiac Arrest (PUCA) study performed by specialised rapid response paramedics ($n = 7$) from Scotland reported median pulse check pauses of 17 seconds (IQR 13-20 seconds) when ultrasound was used. The PUCA study used an audible 10 second countdown to improve times but only had a 60% adherence rate (Reed et al., 2017). What is not well documented or understood is the root cause of ultrasound pulse check

prolongation. The PUCA study has several limitations, including a small participant size of seven paramedics and incomplete data collection due to technical issues. Also, the paramedics were not supernumerary, performing additional critical care tasks such as scene management and advanced skills. These limitations may have negatively impacted the results of ultrasound use in cardiac arrest.

A paramedic-led simulation study by Younger et al. (2016) demonstrated that paramedics could perform a focused echo exam within the 10 second pulse check 96.7% of the time in a simulated environment after one training day. However, the study design included low participant numbers (n = 10) and repeated assessments and interpretations were measured but not reported. A study by Hayhurst et al. (2011) included 50 cardiac arrest patients who underwent an echo during cardiac arrest resuscitations in the ED. They reported a 90% adherence to the 10 second pulse check by emergency physicians. In their discussion, Hayhurst et al. (2011) mention that no ultrasound scans compromised advanced life support management. However, there is no information on how the 10 second timeframe was adhered to.

In the studies reviewed, ultrasound use in cardiac arrest was primarily investigated in the ED. This propensity may be attributed to the availability of ultrasound devices in the ED and trained emergency physicians to use ultrasound during resuscitation. Studies where pulse check durations were recorded are shown in Table 3.

An interventional study by Gaspari et al. (2021) demonstrated extended pulse check pauses to 28.3 (95% CI [25.1, 31.5]) seconds. However, a post-intervention pre-pause imaging technique improved pauses to 12.8 seconds (95% CI [11.9, 13.7]). In contrast, Lien et al. (2018) reported timings as low as 9.0 seconds for ultrasound application using a systematic evaluation of the inferior vena cava, heart and lungs. Clattenburg, Wroe, Gardner,

et al. (2018) observed a reduction from 19.8 seconds to 15.8 seconds post-intervention using the CASA exam protocol. These findings support the effectiveness of structured ultrasound protocols and pre-imaging to potentially enhance the efficiency of ultrasound during the 10 second pulse check pause.

In addition, when comparing simulation versus the ED setting, there are noticeable differences in the study outline and participant characteristics. Studies by Chin et al. (2013) and Reed et al. (2017) primarily involved out-of-hospital real patient settings. In comparison, Younger et al. (2016) and Booth et al. (2015) involved training paramedics and EMTs and evaluating education interventions using simulation to assess the feasibility of ultrasound during resuscitation. In contrast, studies in the ED setting, such as those by Gaspari et al. (2017), involve larger sample sizes using experienced emergency physicians to evaluate clinical utility and real-world application. Overall, simulation focuses on education and feasibility, whilst ED settings evaluate protocols and live applications during real resuscitations.

2.1.4 Ultrasound Image Acquisition and Interpretation

An important element of ultrasound is the ability to acquire and interpret the image. A pilot educational trial by Rooney et al. (2016) used a convenience sample of 20 paramedics. Their trial examined the ability of paramedics, after 3 hours of training to use the Prehospital Assessment with Ultrasound for Emergencies (PAUSE) protocol. Of the 20 paramedics, only four achieved a written examination score of > 80% required to progress to the field study. Results from the four study participants showed echo views were considered adequate for interpretation and diagnosis for 89% of patients. In these patients, diagnostic accuracy was 100% differentiated between cardiac standstill (asystole) and myocardial activity (Rooney et al., 2016). A scan was considered adequate if the paramedic considered the image readable.

However, images were not moderated or externally reviewed and may not indicate true image adequacy. An earlier study of military medics by Backlund et al. (2010) showed that with 4 hrs of training, 92% of images acquired were considered adequate for diagnostic purposes. Their study also developed a system to scale ultrasound image quality called the Cardiac Ultrasound Structural Assessment Scale (CUSAS). This 6-point grading scale numerically represented the degree of visible ventricle and myocardium. A score ≥ 3 was deemed an adequate image for diagnostic interpretation of cardiac activity (Backlund et al., 2010). Image adequacy quality standards are an important feature in interpreting the image. The CUSAS adopted for this study to measure ultrasound image adequacy.

In 2017, the International Federation for Emergency Medicine (IFEM) wrote a consensus statement to manage undifferentiated hypotension in cardiac arrest patients. After evaluating two international multi-centre prospective studies integrating point-of-care ultrasound in resuscitation, they recommended a structured approach to sonography in hypotension evaluation during cardiac arrest. The Sonography in Hypotension and Cardiac Arrest (SHoC) protocol is a practical checklist standardising cardiac arrest and hypotension scanning based on the ‘4 F’ acronym: Fluid, Form, Function, and Filling. The SHoC protocol targets the most common disease incidence and urgency, including core and supplementary views during cardiac arrest. Core ultrasound views are performed during the pulse check pause using subcostal or parasternal cardiac windows. These views assess fluid (pericardial effusion), form (ventricular) and function (organised cardiac activity) of the heart. Supplementary views examine the lungs (for pneumothorax) and inferior vena cava (for size and filling) (Atkinson et al., 2017). An integral part of the SHoC cardiac arrest protocol includes a verbal checklist to improve team dynamics. The SHoC protocol was created by an ultrasound specialist subcommittee of the Australasian College for Emergency Medicine and the Ultrasound Working Group to include recommendations from the International Liaison

Committee on Resuscitation (Atkinson et al., 2017). The SHoC checklist is for hospital-based resuscitation; however, elements may be transferable to the out-of-hospital setting.

2.1.5 Summary

The literature indicates that using ultrasound during cardiac arrest can be beneficial if applied promptly. However, there are uncertainties regarding its integration into the resuscitation process, especially in out-of-hospital settings. Concerns arise about potential delays in the crucial 10 second pulse check pause, which might reduce the effectiveness of CPR. Factors unique to the out-of-hospital environment, like scene management challenges and other clinical demands, might distract an ultrasound-trained paramedic and cause extended pulse check pauses compared to in-hospital scenarios. A potential solution could be to create a dedicated role for the ultrasound paramedic, combined with a pre-imaging technique. Yet, this combined approach has not been tested in the out-of-hospital context.

2.2 Literature Review of Prehospital Ultrasound Education

This review examines the literature published on EMS ultrasound education. The aim is to identify present-day ultrasound uses in New Zealand and abroad, evaluating the pedagogical principles of education design, delivery, curriculum and assessment. The review identifies what has been accomplished to build on previous work and gaps within the literature (Grant & Booth, 2009). The review centres on journal articles and references from the selected articles.

2.2.1 Method of the Literature Review

The electronic databases: CINAHL complete, Science Direct, PubMed via EBSCO and Google Scholar were searched on the 12th of September 2020. Articles reviewed were refined using custom dates from 2005 to 2020 and full text articles. The exclusion of articles prior to 2005 was due to the relatively new use of ultrasound in the prehospital setting. Key words and phrases used for the literature search were point of care or POCUS or ultrasound or echo* AND paramedic or EMS or emergency medical service or prehospital or ambulance or emergency medical technician or EMT AND education or school or learning or teaching or classroom or education system shown in Table 4.

Table 4

Literature Review Search Terms - Education

Line	Search term	Theme
1	"point of care ultrasound" or POCUS or echo* or "focused echo*"	ultrasound
2	paramedic or EMS or emergency medical service or prehospital or pre-hospital or ambulance or emergency medical technician or EMT	EMT
3	education or school or learning or teaching or classroom or education system	Education

Note. " " = search phrase, * = any ending

The author completed the literature search and review. Articles reviewed were entered into a review matrix and scaled according to their relevance from one to four: One is irrelevant, two borderline, three relevant and four important. A summary of papers reporting education of ultrasound is shown in Table 5. Abstracts, editorials, and letters were excluded due to insufficient data. Literature identified for inclusion or exclusion is depicted using a PRISMA flow diagram presented Appendix F.

The review process identified various studies from different regions demonstrating global interest in using ultrasound in education. Twelve studies were conducted in the United States of America (Ault et al., 2015; Backlund et al., 2010; Bhat et al., 2015; Chenkin et al., 2008; Chin et al., 2013; Heegaard et al., 2010; Lane et al., 2015; Mason et al., 2019; Moore, 2013; Paddock et al., 2015; Press et al., 2013; Raio et al., 2009). Three studies in Canada (D'Alessandro et al., 2018; Guy et al., 2019; Johri et al., 2018), two from Australia (Meadley et al., 2017; Roline et al., 2013), one in Africa , one from Lebanon (El Sayed & Zaghrini, 2013) and one from Hong Kong (Hon et al., 2019). Furthermore, seven studies were conducted in European countries including Germany and the United Kingdom (Booth et al.,

2015; Brooke et al., 2012; Gradl-Dietsch et al., 2018; Oliveira & Lawrence, 2016; Price, Ilper, et al., 2010; Reed et al., 2017; Younger et al., 2016).

Table 5

Summary of Papers Reporting Education of Ultrasound

Author	Title	Location	Study Design	*n*	Main Theme	Evaluation 1-4
Press, G., 2013	Evaluation of a training curriculum for prehospital trauma ultrasound.	United States of America	Prospective observational cohort	34	Our objective was to evaluate the effectiveness of an extended focused assessment with sonography for trauma (eFAST) training curriculum incorporating multiple educational modalities. We also aimed to determine if certain demographic factors predicted successful completion.	3
Mason, R., 2019	Teaching Flight Nurses Ultrasonographic Evaluation of Oesophageal Intubation and Pneumothorax.	United States of America	Observational study - Education	12	To rule out PTX and oesophageal intubations before flight.	2
Hon, S., 2019	A short report on the acquisition of point-of-care ultrasound skills and knowledge by ambulance personnel in Hong Kong.	Hong Kong	Prospective observational study	17	FAST skill acquisition.	2
Guy, A., 2019	A Blended Prehospital Ultrasound Curriculum for Critical Care Paramedics.	Canada	Prospective convenience sample	17	Implementation and evaluation of a prehospital ultrasound curriculum using a blended model of traditional didactics and hands-on experience with online prereading.	4
Gradl-Dietsch, G., 2018	Basic echocardiography for undergraduate students: a comparison of different peer-teaching approaches.	Germany	Observational study - Education	79	The aim of this study was to assess the impact of different teaching interventions in a peer-teaching environment on basic echocardiography skills and to examine the influence of gender on learning outcomes.	2

D'Alessandro, C., 2018	Paramedic POCUS, Turning Our Heads to the Prehospital Side of the Fence: A Narrative Review of Education, Training and Future Direction.	Canada	Narrative Review	-	Narrative review of education.	3
Johri, A. M., 2018	Cardiac Point-of-Care Ultrasound: State-of-the-Art in Medical School Education.	Canada	Review	-	Review of POCUS training and methods of delivery.	2
Salmon, M., 2017	Getting It Right the First Time: Defining Regionally Relevant Training Curricula and Provider Core Competencies for Point-of-Care Ultrasound Education on the African Continent.	Africa	-	-	Link training programs to hospital systems, prioritize longitudinal learning models, share resources to promote health equity, maximize access, and develop a regional consensus on training standards and credentialing.	2
Reed, M. J., 2017	Introduction of paramedic-led echo in life support into the prehospital environment: The PUCA study.	United Kingdom	Prospective observational study	7	Provided education and evaluation for the PUCA study.	4
Meadley, B., 2017	Educational standards for training paramedics in ultrasound: a scoping review.	Australia	Scoping review	-	Evaluation of different educational approaches used for training paramedics in ultrasound in the out-of-hospital setting.	2
Younger, P., 2016	Can paramedics perform and evaluate a focused echo during a simulated 10 second pulse check after 1-day training course.	United Kingdom	Observation education study	10	To assess whether paramedics can be trained to perform basic echo in a 10 second pulse check during simulated ALS results.	3
Oliveira, L., 2016	Ultrasound-Guided Peripheral Intravenous Access Program for Emergency Physicians, Nurses, and Corpsmen (Technicians) at a Military Hospital.	United Kingdom	Observational study - Education	65	Improve the efficiency of practice by implementing ultrasound guidance for PIV access.	1

Booth, K., 2015	Training paramedics in focussed echo in life support.	United Kingdom	Prospective pilot observational study	9	To determine whether paramedics can be trained to perform and interpret focused echo in life support for the assessment of cardiac movement and the recognition of reversible causes.	3
Paddock, M. T., 2015	Disaster Response Team FAST Skills Training with a Portable Ultrasound Simulator Compared to Traditional Training: Pilot Study.	United States of America	Prospective RC blinded Pilot study	36	Determine image acquisition.	2
Lane, N., 2015	Ultrasound in medical education: listening to the echoes of the past to shape a vision for the future.	United States of America	Review	-	Review of ultrasound medical education.	2
Bhat, S. R., 2015	Prehospital Evaluation of Effusion, Pneumothorax, and Standstill (PEEPS): Point-of-care ultrasound in Emergency Medical Services.	United States of America	Prospective observational study	57	This study assesses the ability of EMS providers and students to accurately interpret heart and lung US images.	3
Ault, M. J., 2013	Peripheral Intravenous Access Using Ultrasound Guidance: Defining the Learning Curve.	United States of America	Prospective study	7	To evaluate the learning curve in PIVUS.	1
Moore, C., 2013	An Emergency Department Nurse-Driven Ultrasound-Guided Peripheral Intravenous Line Program.	United States of America	Review	-	To evaluate the UGPIV introduction.	1
El Sayed, M. J., 2012	Prehospital emergency ultrasound: a review of current clinical applications, challenges, and future implications.	Lebanon	Review	-	Review imaging modality improvement in diagnostic accuracy.	3
Brooke, M., 2012	Acquisition and interpretation of focused diagnostic ultrasound images by	United Kingdom	Prospective observational cohort	36	To establish whether UK paramedics have the necessary cognitive, psychomotor, and affective capacity to acquire the necessary	4

	ultrasound-naive advanced paramedics: trialling a PHUS education programme.				skills to incorporate ultrasound examination into their routine assessment of patients after a short programme of education and training.	
Price, S., 2010	Peri-resuscitation echocardiography: Training the novice practitioner.	Germany	Prospective observational cohort	204	To determine the effectiveness of a number of different educational methods used to teach echocardiography to novices. This involved the assessment of cognitive and psychomotor skills and affective aspects in five key areas.	4
Heegaard, W., 2010	Prehospital ultrasound by paramedics: results of field trial.	United States of America	Prospective observational study	25 EMT	To determine if 9-1-1 paramedics trained in ultrasound could adequately perform and interpret the Focused Assessment Sonography in Trauma (FAST) and the abdominal aortic exams in the prehospital care environment.	3
Backlund, B. H., 2010	Pilot Study to Determine the Feasibility of Training Army National Guard Medics to Perform Focused Cardiac Ultrasonography.	United States of America	Prospective observational study	12	To assess the ability of Army National Guard combat medics to perform a limited bedside echocardiography to determine cardiac activity after a brief training module.	4
Chin, E. J., 2013	A Pilot Study Examining the Viability of a Prehospital Assessment with Ultrasound for Emergencies (PAUSE) Protocol.	United States of America	Prospective education intervention pilot	20	The goal of this study is to determine if prehospital care providers can learn to acquire and recognize ultrasound images for several emergent life-threatening conditions, including pneumothorax, pericardial effusion, and cardiac standstill, using the novel PAUSE protocol after a brief training session.	3
Roline, C. E., 2013	Feasibility of bedside thoracic ultrasound in the helicopter emergency medical services setting.	Australia	Prospective pilot study	71	To evaluate the feasibility of bedside thoracic ultrasound in the prehospital HEMS setting. While in flight, providers completed limited bedside thoracic ultrasounds with the patient supine and recorded their interpretation of the presence or absence of the	2

					ultrasonographic sliding lung sign on a closed data-set instrument.	
Raio, C., 2009	Can emergency medical services personnel identify pneumothorax on focused ultrasound examinations?	United States of America	Educational study	33	To determine the sensitivity and specificity of emergency medical service in identifying pneumothorax on ultrasound examinations.	2
Chenkin, J., 2008	Procedures can be learned on the Web: a randomized study of ultrasound-guided vascular access training.	United States of America	Randomized controlled noninferiority trial	21	Sought to determine whether a Web-based tutorial is at least as effective as a didactic lecture for learning ultrasound-guided vascular access.	2

Note. HEMS – helicopter emergency medical service, POCUS – point of care ultrasound, UGPIV – ultrasound-guided peripheral intravenous access, PIVUS – peripheral intravenous ultrasound, PUCA – paramedic ultrasound in cardiac arrest, FAST – focused assessment sonography in trauma, eFAST – extended focused assessment sonography in trauma, PTX – pneumothorax.

Grading Matrix

1- Irrelevant, promising title but content too distant from the topic

2 - Borderline, somewhat peripheral might be worth including depending on research findings

3 - Relevant, useful background material. Similar to other studies

4 - Important, directly relevant to the topic. Established basis for future research

2.2.2 Precursory Testing

Precursory testing is used to benchmark a candidate's pre-existing knowledge. Many of the studies reviewed used a pre-and post-course multiple-choice testing (MCQ) to highlight the effectiveness of education content and the improvement of candidate knowledge. The number of questions within each study test reviewed ranged from 15 to 75, with some integrating video clips showing normal and abnormal pathology. A pre-course test prepared by Press et al. (2013) combined probe placement and position, identification of structures and findings and interpretation of an eFAST video clip into 25 computer multiple-choice questions. Of the 34 candidates completing that MCQ, the mean pre and post-test scores were 43% and 78%, a mean improvement of 35%. Most often, the pre-course test was administered post-course for comparison. Adding pre-and post-course testing is necessary for bench marking and knowledge retention. The timing of post-course test delivery varied from immediately after course completion to 6 weeks later (Bhat et al., 2015; Press et al., 2013). Considering that all the studies reviewed used pre-or post-testing, the suggestion is to integrate this concept into future research projects. The timing of post-course test delivery varied within the studies reviewed, and this may be important when considering knowledge retention and skill fade.

2.2.3 Online Learning

Alternative learning strategies, such as online or web-based education, are an accepted form of learning and can potentially replace classroom lectures (Platz et al., 2011). The modern-day tech-savvy paramedic is governed by work and duty time limitations, making web-based learning achievable (NZ Transport Agency, 2017). The advantages of web-based learning include access to high-quality education anytime and anywhere, various content, student progress tracking and self-directed learning (Chenkin et al., 2008; Press et

al., 2013). Traditional teaching methods of ultrasound involve didactic training and proctored scanning; however, with free open-access medical education, self-directed learning with up-to-date free material is an attractive medium (Guy et al., 2019; Lane et al., 2015). This once classroom-based program has evolved, blending face-to-face with web-based education (Lewiss et al., 2014). A web-based platform also allows the integration of module checkpoints through quizzes and interactive testing.

Chenkin et al. (2008) compared classroom and web-based learning in ultrasound-guided vascular access. Both groups participated in 1 hour of learning and 2 hours of didactic individual self-guided practice. Following a 2-week cooling-off period, each participant completed an Objective Structured Clinical Examination (OSCE) comprising four stations of 8-minute duration. The result showed no statistical difference between the two groups. Both web and classroom learning were as effective as each other. Out of interest, the web-based group were granted continued access to refresh their skills, accessed an average of 3.4 times (range 1 -7) over the study period.

2.2.4 Classroom and Didactic Hands-on Training

Mastery of ultrasound skills requires progressive development and proficiency, likely supported by appropriate training and education (Younger et al., 2016). Considering the absence of an out-of-hospital specific accredited education pathway for ultrasound in New Zealand, future education and program development will rely on existing literature and evaluations of current programs. This initiative aims to incorporate prehospital ultrasound as a specialized level of practice within a comprehensive career framework. The CAFE exam is seen as part of PEA cardiac arrest evaluation for ultrasound trained paramedics.

Emergency ultrasound encompasses five nominal categories: Resuscitative, Diagnostic, Sign or Symptom Based, Procedural Guidance, Therapeutic and Monitoring

(American College of Emergency Physicians, 2016). Much of the work improving safety and education has been established by various hospital-based institutions, with emergency physicians taking a clinical leadership role (American College of Emergency Physicians, 2016). The common education modality within the reviewed literature combined didactic lectures and hands-on training. Lecture duration ranged from 5 minutes with small group simulation labs to comprehensive 2-day courses (Backlund et al., 2010; Guy et al., 2019; Price, Ilper, et al., 2010). Most hands-on training separated students into small groups with a 3:1 or 4:1 student-instructor ratio. Ultrasound was performed on volunteers, simulation mannequins and computer-generated simulation. On average, classroom teaching duration was 2.5 hours (5 mins to 5.25 hrs), and hands-on time was 3.2 hours (15 mins to 5.45 hrs). The content of lectures was specific to each study, with most including basic ultrasound concepts (knobology), scanning technique, interpretation, and application.

Ultrasound Clinical Examination Assessment. The traditional written assessment is a comprehensive demonstration of theoretical knowledge and remains a prominent measurable criterion for examination today. However, ultrasound performance is a didactic psychomotor skill necessitating OSCE. The challenge of psychomotor assessment is developing a framework that ensures the validity and reliability of scoring, examiners, and patients (Todsen et al., 2015). The OSCE is a generic health sciences examination tool examining the learner's skills and knowledge with carefully written instructions detailing tasks and information supplied when required. Stations are accompanied by an examiner who marks against a structured scheme or rubric. Candidates accumulate marks if they perform a task correctly (Harden et al., 1975).

In this review, several studies mentioned using an OSCE assessment tool; however, one criticism is that there is no standard for these assessments including variation in duration

of assessment, content, scoring and criteria. Standards used within these studies could not be compared due to inconsistency or lack of information. Tolsgaard et al. (2013) initiated a Delphi consensus study to identify key elements specifically required for ultrasound certification and recertification standards. On the third Delphi round the consensus panel identified seven essential factors for assessment resulting in the development of the Objective Structured Assessment of Ultrasound Skill (OSAUS). The OSAUS is designed to test proficiency in several aspects related to ultrasound, including the use of equipment, optimising image quality, adopting a systematic approach to examinations, and interpreting the images. Building on this, Todsen et al. (2015) who was also a contributor to the Delphi consensus study, examined the reliability of the OSAUS rating system. The study by Todsen et al. (2015) assessed 24 doctors of varied ultrasound experience as they performed POCUS abdominal scans. Their results found the OSAUS tool to be both reliable and beneficial.

The utilisation of a standardized framework like the OSAUS in ultrasound assessments, ensures a consistent and fair evaluation against a recognised benchmark. Setting the standard for education and assessment is pivotal in the proficiency and development of ultrasound competence. As part of the OSCE experience, simulation software and devices can provide a useful training platform.

Simulation. The notion of feeling competent requires a high degree of hands-on training. Blehar et al. (2015) explain that to achieve a base level of competence in ultrasound, the sonographer must achieve 20 to 25 scans per exam. Providers may not have established relationships with ED's or other providers in the prehospital sector to gain hands-on clinical experience. Simulation-based education is a training solution ensuring a structured, safe environment to become proficient at mastering the skills of probe technique, image acquisition and interpretation (Lewiss et al., 2014; Sidhu et al., 2012). A prospective study

conducted by Knudson and Sisley (2000) examined 74 emergency medicine residents, comparing hands-on training with simulation only. There was no significant difference between the hands-on training and ultrasound simulators. Research shows that students retain information more readily when applying it to a clinical situation such as simulation (Lane et al., 2015). The addition of simulation ultrasound may be a viable option, especially in areas where patient contact may be low. A summary of education learning modules reviewed within the literature is shown in Table 6.

Table 6

Education Summary of Learning Modules Reviewed

Author	Method of Instruction and Assessment
Press et al, 2013	eFAST *Stage 1 Pre-training test* – 25 MCQ (computer based) *Didactic lectures* – 2 hrs (classroom) • 40 minutes of basic ultrasound concepts • 40 minutes of abdomen and eFAST ultrasound • 20 minutes of cardiac ultrasound • 20 minutes of lung ultrasound *Hands-on training* (4 hrs, instructor ratio 4:1) • Two groups rotated through four stations • eFAST performed at each station • Ultrasound views – eFAST (hepatorenal, splenorenal, suprapubic, subxiphoid, parasternal long axis and mid-clavicular for lung) • Images captured – still and 4 second clips of cardiac and lung views *Stage 2 Proctored Scanning* - 6-week period • Two groups attend 4 hrs proctored 1:1 in the ED, performing minimum of four eFAST exams on actual patients. *Internet-based Education Modules* - six modules 10-20 minutes long • Module 1: Introduction to eFAST • Module 2: Image optimization technique • Module 3: Positive eFAST recognition • Module 4: Maximising accuracy avoiding false negatives • Module 5: Maximising accuracy avoiding false positives *Review Didactic Session* – completion of stage 2 (classroom) • 1-hour eFAST techniques and image revision *Post-training Test and OSCE* **–** completion 6 weeks training

	• Pre-test was re-administered as a post-test • OSCE included three eFAST scans on three different patients. Two with ascites and one normal (no findings) • Check list scored transducer technique, image acquisition, appropriate gain, depth and image interpretation *Remediation* – 4 hrs • Post-test students who failed underwent proctored scanning similar to the hands-on training session
Hon et al, 2019	eFAST *Pre-course reading materials* • Course material sent one week prior to course commencement *Course content* *Topics/Lectures* • Introduction 15 minutes • Physics and knobology 30 minutes • How to do FAST? 30 minutes • Prehospital FAST: why and when? 30 minutes *Hands-on training – 25 minutes sessions, instructor ratio 4:1* • Abdomen and pelvis • Lung and cardiac • Simulated FAST • Free practice • Case studies • FAST for triage • Trouble shooting and pitfalls • Scanning in unfriendly environments Total live scanning equalled 200 minutes. Scanning used the SonoSim® ultrasound education training product. *Testing* • POCUS skills test – 45 minutes • 25 MCQ test – 35 minutes
Paddock et al, 2015	eFAST Training Protocol -Compared Simulator ultrasound training verses traditional ultrasound training:

	Pre-course testing (ultrasound and eFAST knowledge) • 74 MCQ assessing key content within the SonoSim® narrative • Ultrasound simulator-based narrated screencast didactics – 90 minutes • Group training – instructor ratio 4:1 • Group A: Traditional skills training 1hr with 15 minutes hands-on time • Group B: Simulator based training 1hr with 15 minutes hands-on time • Group C: Traditional skills and simulator-based training 2 hrs • Groups A, B and C assessed: ○ Standardized direct observation skills assessment ○ FAST image interpretation skills assessment ○ Post-course ultrasound and FAST knowledge evaluation
Heegaard et al, 2013	EFAST Study Protocol, instructor to ratio 4:1 Lectures, written pre/post exams and OSCE Course 6 hrs: • Physics and image orientation 60mins • FAST exam 40 minutes • Case review of each quadrant 20 minutes • Abdominal aorta 40 minutes • Case reviews of AAA 20 minutes • Practical training 180 minutes • Each participant received two 1-hour refresher course during the 1-year study period
Gradl-Dietsch et al, 2018	ECHO Pre-course 15 MCQ exam *Random assigned four groups:* • Peer teaching • Peer teaching using Peyton's four step approach • Team based learning • Video based learning

	Course (practical) two sessions 90 minutes each • Cardiac windows (PSLA and A4C) • Pathological findings • Post-course 15 MCQ exam • OSCE single station (two windows and identify anatomical structures within 5 minutes)
Booth et al, 2015	ECHO • Training Protocol • Pre- and post-course questionnaire – establish knowledge • Course competition – OSCE • Perform PSLA and SC4 • Perform both scan windows within a simulated 10 second pulse check
Younger et al, 2016	ECHO Training Protocol *Pre-reading College of Emergency Medicine Ultrasound eBook (2010)* *1-day course 6 hrs* • Classroom based learning 3 hrs • Practical session 3 hrs with an instructor at each station 2:5 ratio. Ultrasounds was performed on each other and a CAE® Vimedix simulator • OSCE • CAE® Vimedix simulator included three pathologies already shown within the teaching. Simulations assessed interpretation, view acquisition <10 sec and correct pathology identification
Price et al, 2010	ECHO *Small group teaching and skills training* • Lectures 20 minutes • Didactic training with 12 hands on stations • Small groups 3:1 instructor ratio • One station incorporated ALS simulation mannequin and anther computerized image identification and interpretation suite (Reslice™ Echo simulator) • OSCE

Backlund et al, 2010	ECHO – 4 hrs • Basics of ultrasonography 5 minutes • Divided into four groups • Didactic training 15 minutes (views taught SC4 and PSA) • Observed by an instructor until satisfactory echo performed • Assessment – four scans on healthy volunteers using SC4/PSA, recording a 3 second clip. Clips were reviewed independently • CUSAS ultrasound assessment score was used
Guy et al, 2019	PHUS *Pre-course reading developed from open access resources* *2-day course 15 hrs 30mins, 4:1 instructor ratio* • Introduction to Equipment 15 minutes • Physics and Knobology Theory 30 minutes • Thoracic Ultrasound Theory and Applications 45 minutes • Abdominal Ultrasound Theory and Applications 45 minutes • Thoracic/Abdominal Practice 1 hr 45 minutes • Hemodynamic Ultrasound Theory and Applications 60 minutes • Hemodynamic Ultrasound Practice 2 hrs • Vascular Ultrasound Theory and Applications 30 minutes • Vascular Ultrasound Practice 60 minutes • General Review of Theory and Applications 30 minutes • General Practice All Scans 3 hrs • Written Examination (30 MCQ and written questions) 60 minutes • Practical Examination of Image Acquisition 2 hrs and 15 minutes each • Debriefing and Feedback 30 minutes Total Time 15 hrs 30 minutes
Brooke et al, 2012	POCUS Training Protocol *2-day course*

	• Review of anatomy and physiology of the chest 45 minutes • Pathophysiology of the chest 45 minutes • Management of critical chest injury 45 minutes • Introduction to the science of ultrasound 45 minutes • Introduction to ultrasound imaging equipment 45 minutes • Image orientation and practical application (practical) 60 minutes • Ultrasound imaging of the lungs 45 minutes • Ultrasound and the diagnosis of pneumothorax 45 minutes • Practical sessions (total) 3 hrs • Video Clip assessment 27 minutes • OSCE 10mins per participant • Post course assessment 2-part examination • Assess ability to detect the presence or absence of PTX using 30 pre-recorded video clips • OSCE
Chin et al, 2013	Echo PAUSE protocol (Prehospital Assessment with Ultrasound for Emergencies) Training Protocol – 2 hrs total • Basics of ultrasonography, PAUSE protocol, image acquisition, basic interpretation for the heart and lungs lecture 1hr • Group didactic session 1:3 instructor ratio 1 hr (lung view, SC4 and PSLA) *No formal instruction on probe orientation, identifying structures, doppler functionality or image quality adjustments. These were deemed unnecessary in identifying cardiac activity or large pericardial effusions* • Exam – followed immediately post course. • Image video clip recognition, 10 questions viewed on a laptop (clips had not been seen by participants previously) • Acquire a view of the left and right plural interfaces and one view of the heart. Cardiac views were scored using the CUSAS assessment
Bhat et al, 2015	PHUS Training Protocol • *Pre-course MCQ, 16 video clips normal/abnormal pathology*

	• Lecture basic scanning, ultrasound anatomy, image interpretation with pathology and lung imaging (1 hr) • Post-test immediately following lecture MCQ 16 video clips same as pre-course in a different order

Note. eFAST = extended focused sonography in trauma, FAST = focused assessment sonography in trauma, AAA = abdominal aortic aneurysm, OSCE = objective structured clinical exam, POCUS = point-of-care ultrasound, PSLA – parasternal long axis, SC4 – subcostal chamber four, PSA = parasternal short axis, CUSAS = cardiac ultrasound structural assessment scale, PTX = pneumothorax, PAUSE = prehospital assessment with ultrasound for emergencies, PHUS = prehospital ultrasound.

2.2.5 Summary

This literature review has revealed a gap in the current landscape regarding ultrasound education methods, assessment techniques, and curriculum content for ambulance staff in New Zealand and internationally. This gap presents a promising opportunity for collaboration between out-of-hospital providers and tertiary education centres to establish a recognised standard encompassing robust education, rigorous assessment, and comprehensive clinical supervision.

The absence of a formal out-of-hospital ultrasound education programme for ambulance staff in New Zealand underscores the need for development in this area by defining ultrasound as a specialist skill.

Chapter 3 Methods

This chapter identifies the methodology and perspective which form the foundation of this research. This is followed by presenting information on the study design, study participants, education programme design, study phases, data sources and measurement acquistion.

3.1 Methodology and Perspective

Identifying methodological perspective forms the research foundation and determines the appropriate methods for answering questions and analysing data (Griffiths & Mooney, 2012). Philosophy defines the assumption of how knowledge and nature are interpreted. The conceptual 'toolbox' of research paradigms outlines this study's guiding principles, frameworks and research construction (Kaushik & Walsh, 2019). The theoretical approach of this research uses a pragmatist philosophy encompassing the freedom to choose the appropriate method, technique and procedures to answer the research question (Žukauskas et al., 2018). Pragmatic philosophy draws from experience and links this to action (Kaushik & Walsh, 2019). Pragmatism resonates with paramedic practice through the practical processes of developing knowledge, drawing from experience, employing clinical decision-making, and providing action-based clinical intervention (Williams et al., 2021). Paramedic practice is conducted using clinical guidelines, and thus, a CAFE ultrasound evaluation tool will be developed and utilised for this research.

In addition to the methodological perspective rooted in pragmatic philosophy, the education pedagogy for this research will leverage constructivist principles, incorporating innovative approaches such as the flipped classroom model (De Vasconcelos Papa & Guilherme Villares Da Costa, 2021). This pedagogical strategy involves delivering

educational content outside the classroom, using an online platform encouraging independent learning. In phase II of the study, the educational approach emphasises active learning with instructors facilitating collaborative face-to-face learning.

This research focuses on informing practice through evidence-based medicine, primarily employing quantitative research methods. Quantitative research generates data and analyses relationships between variables (Curtis & Drennan, 2013). The existing literature is insufficient to address the integration of ultrasound into OHCA in New Zealand. This research aims to provide additional knowledge and education. In the context of this study, the term ‘author’ refers to the lead researcher, Hannah Latta, and is used throughout the work.

Research bias and preconceptions are pivotal in shaping meaningful scientific outcomes within paramedicine and ultrasound education. Acknowledging potential biases and ensuring transparency about the authors’ prior experiences are crucial steps addressed through study design and the transparent use of tools to demonstrate objectivity and reliability. The author’s prior ultrasound education experience can influence curriculum development and teaching methods. Being mindful of these biases and actively collaborating with experts outside of paramedicine fosters trust and neutrality and enhances reliability.

3.2 Study Design

This study uses deductive quantitative scientific enquiry through observation, competency assessment and evaluation of simulated interventions. The deductive method is appropriate to explore the variables through empirical data collection and quantitative analysis and uses simulation as a training methodology. This chapter reports using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (Myriam & Matthias, 2014) and the International Network for Simulation-based Paediatric

Innovation Research and Education (INSPIRE) statements for transparent reporting (Cheng et al., 2016). The Society for Simulation in Health Care Consensus Group created the INSPIRE guideline to develop and improve simulation research reporting. This guideline is an extension of STROBE, allowing the critical appraisal of simulation strengths, weaknesses and study replication.

This study has three phases. Phase I is an eLearning education module using a flipped classroom approach to pre-learning before hands-on practical training. The flipped classroom shifts the focus to student-centred learning by presenting traditionally classroom-taught material on an online platform. This approach allows the learner to participate in the modules during their own time, managing shift work requirements and reducing the burden of attendance in the classroom.

Phase II provides practical and theoretical education and initial competency-based assessment in the classroom. These assessments include onsite, online knowledge tests, ultrasound integration into simulations, a fluid and function evaluation of the ultrasound images termed the CAFE exam and echo skills competency testing.

Phase III is a repeat of phase II assessments with an additional simulation station assessment. Phase III reduces fatigue with the inclusion of assessments only. Progression through each phase builds on the participants' knowledge and experience in preparation for the final assessments in phase III. This sequence provided safe, structured, and supportive strategies to generate effective scientific knowledge acquisition.

3.2.1 CAFE Exam Summary

The cardiac arrest-focused echo (CAFE) exam is a focused ultrasound interpretation for PEA cardiac arrest developed specifically for this study. The CAFE exam is a modified

version of the SHoC exam by Atkinson et al. (2017) specifically focusing on the presence of fluid and function of the left ventricle encompassing myocardial contractility (squeeze) and valvular movement indicating forward flow. The exclusion of 'filling', which evaluates the inferior vena cava and 'form' determining right heart enlargement for signs of PE, was considered beyond the clinical scope of novice ultrasound paramedics. The focused clinical questions of the CAFE exam evaluate fluid and function:

- Is there a pericardial effusion causing tamponade?
- What is the degree of ventricular contraction (squeeze)?
- Are the valves opening, indicating forward flow?

These questions are asked during the 2 minutes of CPR in the cardiac arrest scenario. A CAFE report form is completed at the of the scenario and reviewed later by two external reviewers.

3.2.2 Study Participants Recruitment

Study participants were a convenience sample of self-selecting WFA paramedics. Paramedics recruitment occurred over 1 month for groups A and B. The recruitment period may have missed participants who were on leave. Wellington Free Ambulance paramedics work 48 hours on an 8-day cycle with two 12-hour day and night shifts followed by 4 days off. Each paramedic is assigned to one of four shift colours red, brown, blue, or green. The nature of shiftwork applies selection bias based on the dates chosen to conduct trial phases. To mitigate this and provide equal opportunity for attendance, group A included paramedics from shifts green and blue and group B from brown and red. For the study size power calculation see Study Size Calculation.

3.2.3 Paramedic Participants Catchment

On March 6th, 2022, 125 employees of WFA held an Authority to Practice (ATP) of paramedic and above (H. Leckie, personal communication March 6th, 2022) and were, therefore, eligible to participate in the study. The distribution of ATPs for WFA staff is shown in Table 7.

Table 7

Wellington Free Ambulance Authority to Practice

Qualification Level	*n*
Paramedic	71
Clinical Paramedic Advisor	11
Extended Care Paramedic	11
Critical Care Paramedic/Intensive Care Paramedic	32
Total	125

3.2.4 Eligibility of Paramedics

Eligibility criteria included employment with WFA holding paramedic level of practice or greater. Entry into the study was limited to paramedic level or above, anticipating alignment with the future use of ultrasound and the implementation of the CAFE exam. Speciality levels included intensive care paramedics, flight paramedics, extended care paramedics and clinical paramedic advisors. Further inclusion requirements included a Bachelor of Health Science in Paramedicine or equivalent qualification and paramedic registration (New Zealand or Australia). Exclusions included previous clinical ultrasound experience.

3.2.5 Recruitment Dates

Due to SARS-COV-2 pandemic disruptions, the study participants were divided into groups 'A' and 'B' with 15 participants per group. Recruitment commenced for group A on the 16th of December 2021 closing on the 10th of January 2022. Group B were recruited on the 1st of April 2022 closing on the 26th of April 2022. Group B study participants were recruited using the same method as group A.

3.2.6 Study Advertisement

With prior approval from WFA, recruitment posters were displayed in high-traffic areas on 10 ambulance stations in the Wellington and Wairarapa region in early December 2021 shown in Appendix G. The ambulance stations included were as follows:

- Life Flight, Rongotai
- Newtown Station
- Thorndon Station
- Johnsonville Station
- Porirua Station
- Kapiti Station
- Lower Hutt Station
- Upper Hutt Station
- Masterton Station
- Greytown Station

On December 16, 2021, an advertisement for group A was placed in the 'Keeping Connected' weekly intranet bulletin staff update available in Appendix H. Group B was advertised on April 7, 2022. Group B was recruited similarly to group A but relied on word-

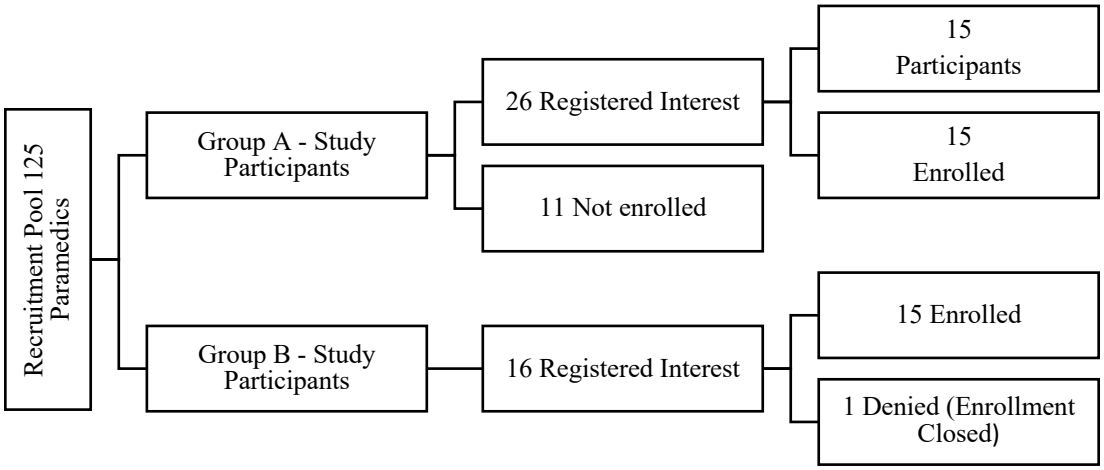
of-mouth between participants and their colleagues to spark interest. Group A study participants were encouraged to discuss their experiences to improve recruitment for group B. Additional information for staff was provided on the WFA SharePoint page, shown in Appendix I.

A short 3-minute synopsis promotional video was also created and is available on YouTube by clicking the following hyperlink CAFE Trial Promotional Video.

Registrations of Interest. Paramedics were asked to register their interest by email. All interested applicants were sent a standardised email reply. Interested paramedics returned a digitally signed consent form to the CAFE Research email address (Cafe.research@wfa.org.nz). Consent forms were downloaded and stored in the author's AUT OneDrive folder titled 'CAFE Research', 'Consent Forms'. The AUT OneDrive was shared with the author's supervisor Dr. Bronwyn Tunnage (BT). Completed consent forms were printed in hard copy and stored on AUT premises in a secure drawer accessible to BT only. Group A included 26 registrations of interest, of which 15 enrolled in the study. Eleven applicants were excluded due to non-availability across all three phases and work or leave cycle requirements. In group B, 16 paramedics registered interest, and 15 enrolled, with one participant missing the deadline for enrolment. Registrations of interest for groups A and B are displayed in Figure 12.

Figure 12

Registrations of Interest and Enrolment Groups A and B



Note. Group A study participants not enrolled were unable to attend due to work commitments. Group B, one registration of interest was received one day after enrolment closed.

3.3 Study Population

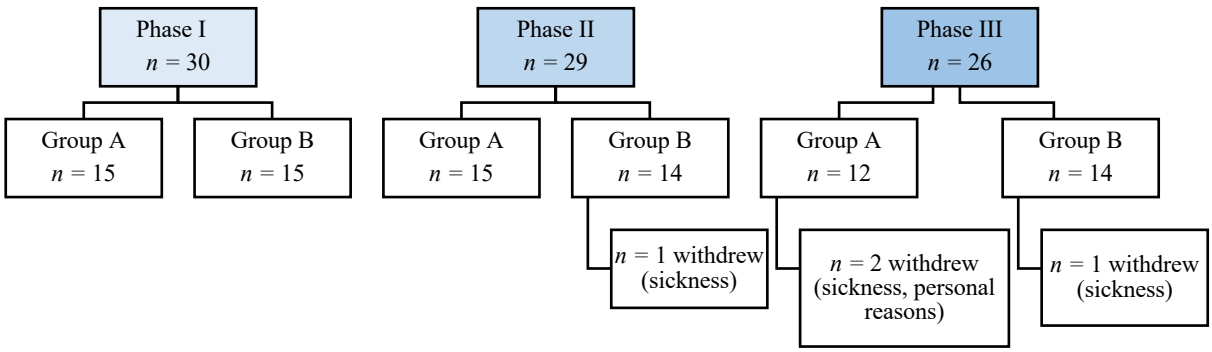
This study sought a convenience sample of 30 self-selecting WFA paramedics based on practical considerations and anticipated outcomes derived from the existing literature, with the goal of achieving statistically significant results. Wellington Free Ambulance was considered a representative sample of New Zealand paramedics based on four similarly published studies ranging from 11 to 40 participants (Aichinger et al., 2012; Chin et al., 2013; Kreiser et al., 2022; Reed et al., 2017; Rooney et al., 2016). All study participants were employees of WFA and met the eligibility criteria described in the section Eligibility of Paramedics. Study participants were to complete each phase sequence before proceeding to the next.

3.3.1 Study Participant Attendance

Attendance in phase I included 30 participants, 15 from group A and 15 from group B. In phase II, 29 attended (group A n =15, group B n =14) and 26 completed phase III (group A n =12, group B n =14) as shown in Figure 13. Participants were assigned to either group A or B, depending on their month of recruitment. Participants did not switch between groups. Of the 30 participants enrolled in the study, one did not complete phase II due to contracting SARS-CoV-2. In phase III, three participants withdrew, one for personal reasons and two from SARS-CoV-2.

Figure 13

Phase Attendance Flow Diagram



3.3.2 Demographic Survey

The anonymity of the survey design posed challenges in following up non-completion, leading to missing data points and incomplete records. However, maintaining anonymity in the survey was important for ensuring participant privacy and confidentiality.

3.3.3 Demographic Data Collection

In phase I, participants were asked to complete an online demographic survey through AUT Qualtrics^{XM} Software. Survey questions asked participant paramedic's demographic characteristics, including age, ethnicity, gender, education, and employment information. Participants accessed the survey through the AUT Canvas page and clicked on a 'flip card' revealing a password (CAFE2022) and a link to the Qualtrics^{XM} website. Survey links and answers were anonymous and could not be tracked or used to identify respondents. Survey data was collated on the 15th of June 2022, and manually entered the IBM® Statistical Package for Social Sciences (SPSS®) for Apple® Mac, version 29.0.0.0 (241). The survey data was incomplete. The study recruited 30 participants, of which 25 responded to the survey, 16 (53%) male and 9 (30%) female. This data was exported from Qualtrics^{XM} and entered manually into the participant database in SPSS®.

3.3.4 Study Participant Characteristics

The characteristics of study participants are presented in Table 8. Ethnicity data were categorized using the New Zealand Ministry of Health's (MOH), Manatū Hauora level one grouping (Ministry of Health, 2017). The study also included demographic information such as gender, age, employment, and education from 25 participants in phase I, with five participants not providing demographic details. No reminders or follow-ups were conducted due to questionnaire anonymity. The study explored gender proportions in the New Zealand paramedic population using a Chi-Square Goodness of Fit test to assess gender disparity.

Among the 25 participants who completed the demographic survey, 16 (64%) identified as male and nine as female, with no participants selecting other gender categories. Over half of the participants (n = 15, 60%) were aged between 20 and 40 years, five were

between 41 and 50, and the rest fell into the 51 to 70 age categories. Nearly all participants (n = 22, 88%) identified as New Zealand European. The majority had over 4 years of ambulance employment (*n* = 23, 92%), with over half having 9 to 20 years of experience (*n* = 17, 68%). Eighteen respondents (58%) held bachelor's degrees, while one participant held a philosophy degree or doctorate, and 11 had postgraduate qualifications. All 30 participants were registered in New Zealand and held either a Bachelor of Health Science in Paramedicine or an approved equivalent qualification (Te Kaunihera Manapou Paramedic Council, 2021). For the purposes of analysis gender was coded in SPSS® to represent categories for example 1 = male and 2 = female.

Table 8

Description of Study Participants' Characteristics by Group

Variable		*n*	%
Gender	Male	16	64%
	Female	9	36%
	(Missing)	(5)	-
Total		25	100%
Age Group	20-30	6	25%
	31-40	9	38%
	41-50	5	21%
	51-60	2	8%
	61-70	2	8%
	(Missing)	(6)	-
Total		24	100%
Ethnicity	NZ European	23	92%
	NZ Māori	-	-
	Pacific Peoples	1	4%
	Asian	-	0%
	Other ethnic groups	1	4%
	(Missing)	(5)	-
Total		25	100%
Ambulance Employment (years)	1-3	2	8%
	4-8	6	24%
	9-12	7	28%
	13-17	3	12%
	18-20+	7	28%
	(Missing)	(5)	-
Total		25	100%
Education	Bachelor's Degree	18	58%
	Postgraduate Certificate	8	26%
	Postgraduate Diploma	3	10%
	Master's Degree	-	-
	PhD or Doctorate	1	3%
	Other (specify)	1	3%
	(Missing)	(5)	-
Total		31	100%

Note. NZ = New Zealand, Education Other = National Diploma. Percentages were rounded to the nearest whole number.

3.3.5 Study Population Goodness of Fit Test

A Chi-Square Goodness of Fit test compared observed gender to the expected values of gender within the New Zealand registered paramedic workforce. Using the observed proportions of male to the female gender, a Chi-Square Goodness of Fit test indicates there was no significant difference in the proportion of males, $\chi^2(1, n = 0.49)$, $p = 0.25$, and females, $\chi^2(1, n = 0.44)$, $p = 0.25$, identified in the study sample (Table 9). The study population was considered a gender-representative sample of New Zealand paramedics. The absence of gender-diverse participants in this study is the rationale for male-to-female comparison only.

Table 9

Chi-Square Goodness of Fit Test

Variable		Observed *n*	Expected *n*	χ^2	*p*
Gender	Male	16	13.2	0.49	0.25
	Female	9	11.8	0.44	0.25
	Total	25			

Note. Twenty-five participants responded to the demographic survey in phase one.

3.3.6 Māori Participation

To address ethnic diversity within the study, preferential inclusion of Māori participation was sought. Methods of recruitment were discussed with WFA cultural advisor Yvonne Gemmell to encourage Māori participation. Despite best endeavours, no participants identified as Māori and one identified as New Zealand Samoan. All other participants were of

New Zealand European or British origin. Participant characteristics are described in the demographics section in Study Participant Characteristics.

3.3.7 Eligibility Instructor Assessors

The author recruited doctors with ultrasound experience from Wellington ED with permission from the Wellington Emergency Department Clinical Director, Dr. Andre Cromhout. Expressions of interest were sought for instructor assessors for phase II and III of the study in December 2021. Advertisements were displayed in ED, high-traffic areas, the staff lounge, and the weekly intranet bulletin. Initial staff interest was low, so further expressions of interest were sought through internal networks and by word of mouth. The eligibility criteria included current ASUM accreditation in the Certificate in Clinician Performed Ultrasound (CCPU) or completing the work required to achieve ASUM accreditation. The latter was included due to SARS-COV-2 delays in the accreditation process for some doctors awaiting final CCPU completion. Recruitment for group B doctors was laborious following the SARS-COV-2 lockdown. In April and May 2022, international borders opened, and many doctors who had volunteered for group A could not attend group B due to travel commitments. Despite this, all doctors who participated were engaged in the practice of emergency medicine and used ultrasound within their practice. The following section describes the CCPU and its relevance as a requirement of the assessor role.

Certificate in Clinician Performed Ultrasound. The CCPU qualification demonstrates proficiency in image acquisition and ultrasound skills relevant to a medical speciality area. The syllabus is modular, including basic echocardiography in life support (BELS), which is a pre-requisite for demonstrating competency to instruct and assess echo ultrasound. The BELS module covered the following course objectives, replicated from the ASUM BELS course objectives (Australasian Society for Ultrasound in Medicine, 2021a):

On completing the BELS unit, learners should be able to understand the following:

- Normal heart and Inferior Vena Cava (IVC) appearance, including IVC collapsibility, pericardial fluid, and chamber collapse
- Learners will be able to identify and discuss the following:
    - Sonographic signs of tamponade
    - Sonographic signs of cardiogenic shock
    - Sonographic signs of massive pulmonary embolism
    - Sonographic signs of sepsis and hypovolemia
    - The Role of Echo in cardiac arrest and its Integration into Advanced Life Support (ALS) Protocols
- Learners will be able to demonstrate the ability to interpret ultrasound in the following settings
    - Echocardiography in the shocked or arrested patient
    - Fluid volume estimate in the shocked patient
- Learners will be able to demonstrate the following skills:
    - 2-dimensional B mode (Brightness mode) Image acquisition:
    - Imaging the heart in parasternal long, parasternal short, apical four-chamber and subcostal views
    - Imaging IVC in longitudinal and transverse planes and assessing IVC size and collapsibility
- Image interpretation:
    - Qualitative assessment of IVC, Left Ventricle (LV) and Right Ventricle (RV) size, LV contractility and volume status
    - Recognition of cardinal ultrasound findings in shock/arrest
- Clinical correlation:

- Integration of clinical picture and BELS findings
- The role of BELS in guiding ongoing resuscitation

The BELS includes a pre-test, 6 hours of learning, 4 hours of practical knowledge and a post-test. Competency assessments include two formative and one summative assessment of clinical skills related to echo in life support.

3.3.8 *Eligibility of Healthy Volunteers*

The author recruited healthy volunteers as models and simulation faculty for phases II and III of the study. The number of volunteers required for each phase and station are shown in Table 10.

Table 10

Healthy Volunteer Numbers Required

Phase	II	III
Scanning Stations	5	-
Simulation 1	3	3
Simulation 2	3	3
Simulation 3	3	-
Echo Assessment	1	1
Total	15	7

Initial eligibility criteria included an ATP of EMT or higher and being a WFA employee or volunteer. Advertising and expressions of interest were sought simultaneously with study participants. Volunteers expressed their interest through the same process as study

participants. Response for both groups, A and B, was lower than expected. Possible reasons for this low response may include pandemic shift work fatigue and personal and study or life commitments. The benefit was less enticing for volunteers but included ultrasound and research exposure. As a result, the eligibility for volunteer recruitment was lowered to allow uptake from a larger pool of WFA staff and paramedic students at Whitireia Community Polytechnic. The author removed the initial requirement for EMT and included first responders (FR) and paramedic students. The author gave preferential entry to volunteers with resuscitation experience.

The author corresponded with Whitireia and WelTech Community Polytechnic Head of Paramedic Science, B. Westenra. With permission from Whitireia, the study was advertised on their Paramedic Student Facebook page, calling for study volunteers. This advertisement was successful, with three Bachelor of Health Science Paramedic students volunteering their time for group B phases II and III. The remaining positions were filled with WFA EMTs, FRs, and patient transfer officers. All phases of the study included five reserve volunteers, all utilised due to sickness.

3.3.9 Research Faculty

The research faculty included staff directly involved with the planning of the research project, Dr. Andy Swain, and volunteers for phase II and III. Assistance was sought from WFA Educator Brendan Harris, who is a registered paramedic with a Bachelor of Health Science (Paramedicine) and a Postgraduate Certificate in Clinical Education, specialising in simulation. Support to faculty staff and assistance with simulations was provided by Celeita Williams, who has 8 years of experience as a paramedic lecturer at AUT with vast simulation experience and is also a registered intensive care paramedic with Hato Hone St John

Ambulance. Celeita Williams has a master's degree in Aeromedical Transport and Retrieval Medicine and is working towards a Doctor of Health Science.

3.3.10 Independent Image Reviewers

The author recruited two independent external moderators to retrospectively review all ultrasound images at the suggestion of Dr. Scott Bomann (external supervisor). Both reviewers are ultrasound experts and leaders in their field. Each reviewer was allocated an alphabet letter for presenting results. Reviewer A was Dr. Darrell Sutijono, a Senior Physician at the Permanente Medical Group in Santa Clara, California. Dr. Sutijono has extensive experience in ultrasound and is a Clinical Assistant Professor (Affiliated) at Stanford University School of Medicine. Reviewer B was Dr. Reinier Van Tonder, an Assistant Professor of Emergency Medicine, and Associate Medical Director of the Yale New Haven Hospital, Saint Raphael's Campus Emergency Department in Connecticut. Dr. Van Tonder is also the Co-Director of Emergency Ultrasound for the Saint Raphael's Campus.

3.3.11 Information Sheet and Consent Form

All participants, including study participants, healthy volunteers, instructor assessors, and external moderators, were provided with an information sheet and consent form. An example of all participants' information and consent forms is shown Appendix J. All participants had the opportunity to withdraw from the study at any time.

3.3.12 Research Budget

The total cost of running this trial amounted to $8,500.53, sourced from multiple funding streams including Auckland University of Technology Doctor of Health Science

Funds, PBRF 'Seed Funding Grant', Heart Foundation Grant, and Wellington Free Ambulance. An itemised budget is shown in Appendix K.

3.3.13 Remuneration

Remuneration for participants was provided in the form of Motor Trade Association (MTA) vouchers. Each participant received a $20 MTA koha[6] towards travel for attending phases II and III. Vouchers were placed in a named envelope and presented to the participants on their arrival at phases II and III.

3.3.14 Additional Remuneration for Doctors

The ultrasound doctors provided their time and experience with no expectation of remuneration beyond the MTA vouchers. One doctor provided 16 hours of their free time over groups A and B, phase II and III. This time commitment could not go unrecognised, and the author applied through AUT School of Clinical Sciences PBRF Fund for a 'Seed funding grant'. The successful application funded additional koha for each doctor, which was allocated based on their time contribution.

3.3.15 Continuing Professional Development Points

Registered paramedics in New Zealand must complete 30 hours of continuing professional development (CPD) annually to maintain their annual practising certificate (APC). For further information on Kaunihera Manapou Paramedic Council Practice Standards see the following link https://paramediccouncil.org.nz/ (Kaunihera Manapou Paramedic Council of New Zealand). Participation in research had not previously been recognised as a form of CPD until this study. To formally recognise the time, clinical

[6] Koha is the Māori term for "a gift or donation"

experience and knowledge acquired through study participation, the author contacted the New Zealand Paramedic Council Registration Coordinator on March 10th, 2022, seeking consideration for CPD allocation for study participants. The Paramedic Council registrar responded by requesting information, including a breakdown of hours, learning outcomes, theoretical knowledge, and hands-on training. The registrar also asked for WFA endorsement. A subsequent email was sent from the author to the WFA Manager of Operations K. Worthington, seeking approval of CPD allocation. The request was approved for CPD point allocation on March 10th, 2022. Points were allocated based on hours of participation. On March 11th, 2022, the CAFE trial was formally recognised and allowed to issue CPD points to study participants. This application of recognition for CPD points has created an avenue for future participants of research studies to have their time and knowledge formally recorded.

3.3.16 Completion Certificate

After phase III, participants, doctors, and support staff were awarded a certificate of completion and CPD hours for claiming points. The certificate was supported by WFA and signed by the author and Dr. Andy Swain, WFA Medical Director. A template of the certificate is shown in Appendix L.

3.3.17 Conflicts of Interest

Given the author's position as a senior critical care flight paramedic with WFA, part-time paramedic lecturer with AUT and author of this project, the concepts of power and influence are essential considerations. To mitigate these influences, transparency regarding the author's background and potential conflicts of interest was crucial. Collaborating with experts outside the paramedicine field provided diverse perspectives and enhanced the

study's neutrality and objectivity. This approach ensured that the research was conducted with integrity, minimal bias, and promoted trustworthiness and scientific rigor.

Participant communication included the use of email and text messages. Text messages were to be used as a quick form of communication due to the dynamic nature of the pandemic and the effect this had on participants, faculty, and the study venue. Most communication was through a neutral email address created for the study to reduce bias. Dr. Andy Swain and the author had access to the study email account secured on the WFA SharePoint site. The author sent general emails, such as study date reminders. Dr. Bronwyn Tunnage handled emails or contact with study participants containing identifiable information such as study Identification (ID) numbers. Dr. Tunnage was not directly involved with the study days, had no physical contact with participants or faculty, and could remain impartial.

Dr. Scott Bomann and Dr. Andy Swain moderated the phase I lecture content. Externally recruited ultrasound doctors conducted assessments in phases II and III. The author provided a teaching role only to remove bias and potential power differentials between author and the paramedic participant. The author is a professional colleague of the participants. If a participant chose to withdraw at any time, this would not have affected them personally or their employment with WFA.

3.3.18 Ultrasound Device Selection

The Philips Lumify® hand-held ultrasound device was selected for this study due to the author's familiarity with the device and an existing relationship with the company, which facilitated the provision of devices for the study. Specifically, a Lumify® phased array cardiac transducer (4-1 MHz) was used with a Samsung™ Galaxy Tablet A to conduct the ultrasound imaging during Phases II and III. This choice of equipment was influenced by the author's

expertise and the availability of resources through collaboration with Philips, ensuring reliable and consistent data collection for the research project.

3.4 Educational Programme

The study's author developed the education program (modules) using freely available information from point-of-care ultrasound literature, incorporating content from accredited providers including ASUM and Australasian College of Emergency Medicine (ACEM). Videos and written content are shown in developed and presented in Phase I are shown in Appendix M and N, respectively.

The education modules, including eLearning, hands-on didactic training, small group simulations, and Objective Structural Assessment of Ultrasound Skill (OSAUS), were reviewed by Dr. Scott Bomann and Dr. Brad Peckler. Dr. Peckler, a full-time consultant at Wellington Hospital, is the clinical lead for the Simulation and Skills Centre and specialises in educational processes. His expertise in simulation assessments positioned him as the optimal candidate to evaluate the CAFE assessment forms.

It's worth noting that OSAUS is an established framework for assessing clinical skills and competencies in doctors, as indicated by Bromley (2000). For this paramedic research, the simulation and echo assessment forms were simplified from the OSAUS structure and ASUM BELS ultrasound competence assessment form. Detailed assessment forms for echo skills and simulations developed specifically for this study are provided in Appendix O and P, respectively.

3.4.1 Study Phase Timeline

This study was divided into three components, phases, I, II and III, each occurring over 1 month spanning three consecutive months. Completion in each phase was required to

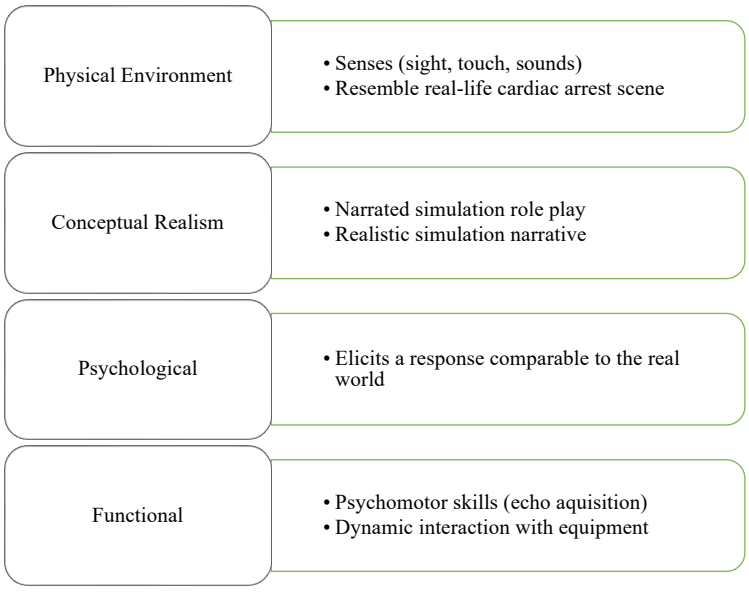
progress to the next phase. The duration of each phase, accommodated participants rostered annual leave, shift colour, healthy work-life balance, and personal time burden.

3.4.2 Simulation, Fidelity and Limitations

Simulation fidelity refers to the accuracy of a simulation in replicating real-world experiences. This includes the authenticity of the physical environment, the realism of the concepts, and the functionality of interactions with personnel and equipment Figure 14. The development of simulations for this study were based on concepts described by Carey and Rossler (2021).

Figure 14

Simulation Fidelity Concepts

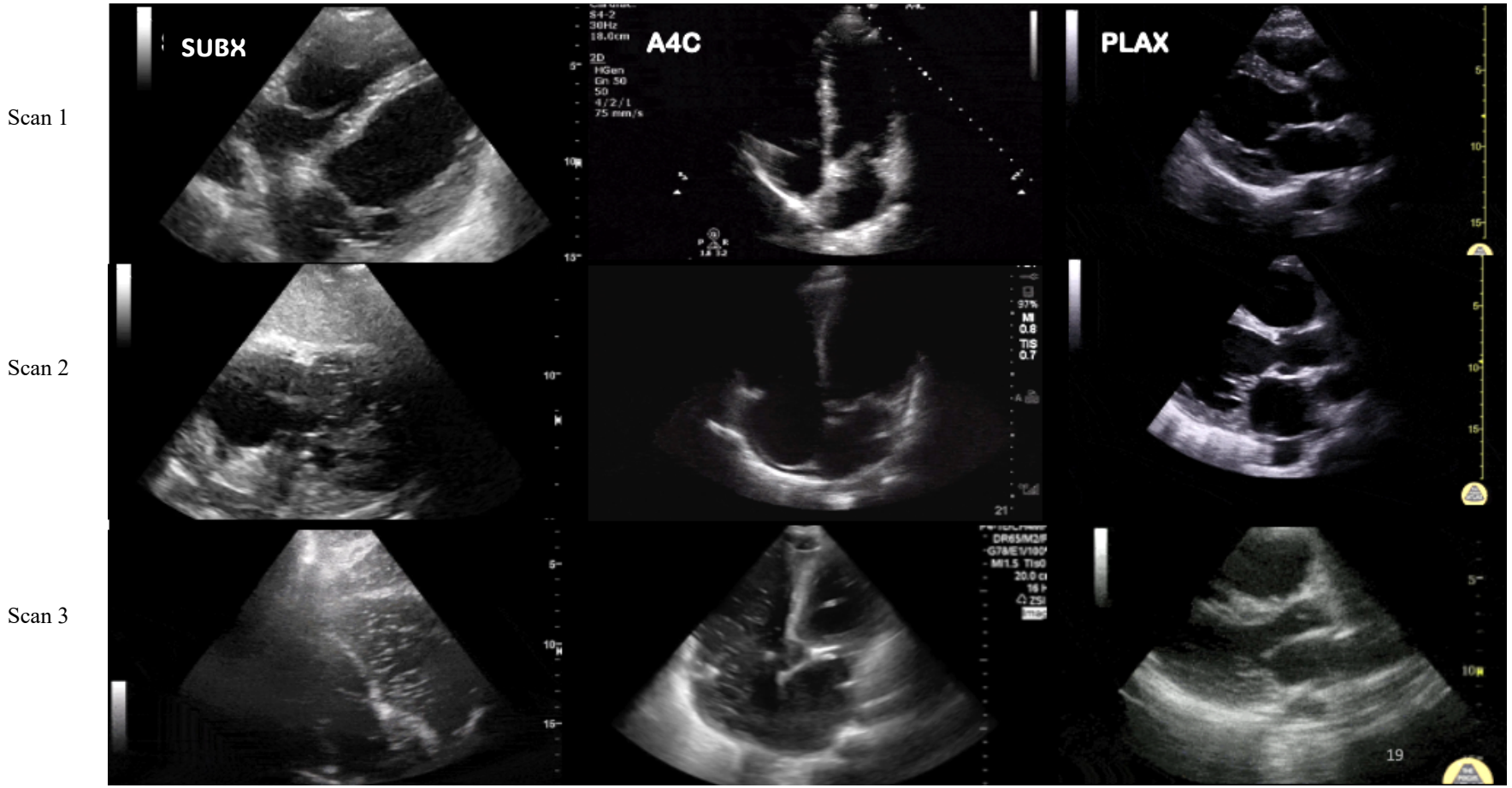


Note. Simulation fidelity concepts used for Phase II and III simulations as described by Carey and Rossler (2021).

The research utilised simulation as an investigative tool to facilitate safe practice and evaluation of ultrasound application without patient risk (Rosen et al., 2008). The use of high-level fidelity through simulation aimed to provide a realistic scene, allowing the participant to achieve the goal of performing the CAFE exam within the 10 second pulse check pause (Carey & Rossler, 2021). Cardiac arrest PEA mock ultrasound images (video loops) were presented to the participant on a tablet during the simulations in place of healthy volunteer images as shown in Figure 15. The participant evaluated the mock ultrasound image and reported their findings using the CAFE exam form.

Figure 15

Simulation Pathological Scan Series



Note. Screen capture of images supplied by the author. SUBX = subxiphoid view, A4C = apical four chamber view, PLAX = parasternal long axis view.

Simulation fidelity limitations included using mock images instead of real-time pathology, potentially affecting the realism and urgency perceived by participants immersed in the cardiac arrest scenario. Despite efforts to enhance fidelity through environmental handling and psychological responses, these limitations may have impacted the immersive experience. Additionally, the limited realism of the simulations may have affected participant performance between simulation stations and phases (Carey & Rossler, 2021).

3.4.3 Clinical Variation

After reviewing the data collected from phase II group A, there was a discrepancy with simulation three. The assessor for simulation three was asked to provide feedback on why the HOT was increased (maximum HOT 27 seconds). The suggestion was that the healthy volunteer scan view was difficult, increasing the HOT. The echo view difficulty was seen as dictating the non-adherence of the simulation team to recommence CPR at 10 seconds. This observation is discussed further in the results and discussion chapters.

The optional refresher training module between phase II and III highlighted the importance of the supernumerary ultrasound operator to the cardiac arrest team as there is a potential to increase pulse check pauses beyond the allotted 10 seconds.

Due to the SARS-COV-2 pandemic, the assessor faculty varied between study groups and phases. The healthy volunteers acting as scanning models also differed between groups and phases. However, variation in healthy model participants increased the variety of echo scanning, possibly representing the operational environment more closely.

3.4.4 Study Participant Identification Allocation

Study participants' names were entered into a Microsoft® Excel Version 16.74 (2023) spreadsheet and emailed to BT, the primary supervisor. By limiting participant liaison to the

primary supervisor, anonymity between the participant and author was maintained. Each participant was randomly assigned one of 30 predetermined identification numbers and eLearning passwords. The tool used to randomise the participants was a web-based Sequence Generator from random.org (https://www.random.org/sequences/). Randomisation occurred on January 18th, 2022, for group A and on April 26th, 2022, for group B. Participants were emailed their identification numbers and passwords by the primary supervisor (BT).

3.5 Phase I Design

Phase I theory-based education was delivered online through an eLearning platform written by the author specifically for this study. These learning modules required completion before attending phase II 1 month later. This section discusses the eLearning platform and describes the learning outcomes.

3.5.1 eLearning Platform

The researcher used the AUT eLearning platform called Canvas. Canvas is a web-based learning management system AUT uses to deliver course learning materials to students. Educators can create and present online materials and assess student's learning. Canvas offers flexibility for learning on any web-based system, including mobile devices, which is essential when considering fatigue, workload, and time management for paramedics during the SARS-COV-2 pandemic. The AUT Learning Transformation Lab approved using Canvas for this study on November 21st, 2021. The development of phase I educational content commenced on November 22nd, 2021. The eLearning content was reviewed by Dr. Scott Bomann and Dr. Andy Swain and approved for delivery in December 2021 and recommendations were incorporated. The eLearning module went live on the January 1st, 2022, to test the platform.

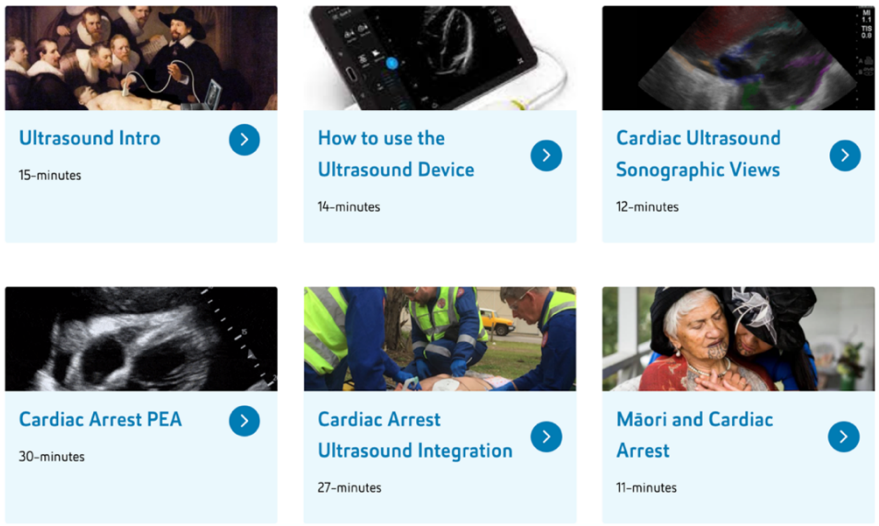
Study participants were invited to login into the AUT Canvas page using their study ID and password where the eLearning platform was available for group A on January 19th, 2022, and B from February 8th, 2022. Phase I was allocated 2-hours however study participants had access to the education platform from phase I to III. Each study participant was required to complete phase I in their own time before attending the face-to-face classroom training in phase II. Phase I completion was confirmed using the Canvas analytics tool. Canvas remained open throughout the study phases for participants to review content as required.

3.5.2 eLearning Content

The content of phase I included a 2-hour online eLearning training package to address basic ultrasound knowledge and cardiac arrest ultrasound integration theory. Study participants were allowed 21 days to complete six learning modules with a specific learning outcome for each. The module tabs are shown in Figure 16.

Figure 16

Canvas Home Page Modules



Note. Screen capture supplied by the author of the Canvas home page taken on February 21st, 2022.

3.5.3 Learning Outcomes

The learning modules were developed with novice ultrasound users in mind, featuring brief instructional videos and concise written material. These modules were intentionally kept short and flexible, catering to the demanding schedules of shift workers. They provided the convenience of being paused and replayed. The following section outlines the learning objectives for each module.

Module One, Introduction to Ultrasound (15 minutes). The module included two 7-minute videos from Clarius 'Fundamentals of Ultrasound', a free and open-access educational video Clarius Fundamentals of Ultrasound (1) Physics. A five-page summary document titled "What is Ultrasound" shown in Appendix M. Learning outcomes included:

1. The study participant will have a basic understanding of ultrasound waves and how ultrasound images are produced.
2. The study participant will have a basic understanding of ultrasound probe technology.
3. The study participant will know to describe the most common ultrasound probe movements of sliding, fanning, rotating, and rocking.

Module Two, how to use the ultrasound device (12 minutes). The module delivered a 7-minute narrated PowerPoint video and 5 minutes of reading including a six-page summary titled 'Transducer Orientation' shown in Appendix N. Learning outcomes included:

1. Basic knowledge of the Lumify® ultrasound device, including how to change ultrasound image depth and gain.
2. Creation of a 'new patient' and ability to enter patient details which were subsequently replaced with a participant identification number.
3. Ability to save a video clip and review the image.
4. Basic knowledge of the cardiac (phased array) probe.

Module Three, CAFE Exam Sonographic Views (12 minutes). The module delivered a 7-minute video demonstrating the echo ultrasound views including the subcostal (SC4), apical four-chamber (A4C) and the parasternal long axis (PSLA). Learning outcomes included:

1. Demonstrating a basic understanding of the essential CAFE cardiac views.
2. Ability to describe sonographic anatomical structures in SC4, A4C, and PSLA view.

3. Knowledge of where to position the probe to obtain a SC4, A4C, and PSLA view.

Module Four, Cardiac Arrest PEA (30 minutes). The module included a 2-minute summary of PEA; a video by Osmosis.org on tamponade physiology which was of 7 minutes duration; and a narrated PowerPoint video discussing the reversible causes of PEA cardiac arrest, and an ultrasound image review which was 22 minutes in duration. Learning outcomes included:

1. Ability to define PEA and pseudo-PEA.
2. Ability to identify the causes of PEA cardiac arrest.
3. Understanding how to optimise an image using DAG (Depth, Axis, and Gain settings).
4. Understanding tamponade physiology and the sonographic signs of tamponade.

Module Five, Cardiac Arrest Ultrasound Integration (27 minutes). The module included a 26-minute narrated PowerPoint video with an accompanying summary PDF. Learning outcomes included:

1. The ability to describe how ultrasound is integrated into PEA cardiac arrest.
2. Understanding the rationale for adhering to the 10 second pulse check pause.
3. Knowing when and how to complete the ‘CAFE Exam Report’.
4. Develop and understand how to assess the scan for fluid and function of the heart.

Module Six, Māori and Cardiac Arrest (11 minutes). The module included an interview with Yvonne Gemmell, Māori Advisor for WFA. The interview theme is “How

does cardiac arrest affect Māori?". This video was created specifically for this study and was written and produced by the author. Learning outcomes included:

1. Awareness of cultural sensitivities for Māori surrounding death and cardiac arrest.
2. Understanding general practices surrounding death for Māori.
3. Understanding the importance of Karakia (prayer) and the Wairua (pathway of spirits).

3.6 Phase II Design

The education included 6 hours of face-to-face learning and hands-on practical ultrasound skills. Study participants' knowledge, echo skills, and CAFE exam integration into the cardiac arrest simulation were also assessed. This assessment provided a benchmark comparator for phase III assessments. This section outlines the training and assessment day, the training and simulation environment, the equipment and the assessment centre for the knowledge quiz and simulation stations.

3.6.1 Training and Assessment Day

The group A training and assessment day was held at the Wellington Simulation Suite on February 9th, 2021, from 0830 to 1525 hours. The main training room was used for PowerPoint lectures, demonstrations, and hands-on ultrasound scanning stations, as shown in Figure 17.

Figure 17

Wellington Simulation Suite Scanning Stations



Note. Photo supplied by the author.

Scanning stations included privacy screens, hospital beds, linen, pillows, Philips® Lumify ultrasound device, cleaning wipes, gloves, and laminated echo anatomy prompt cards. The echo prompt cards provided supplementary reference material for sonographic anatomy, CAFE exam assessment process, and echo and simulation assessment requirements. Prompt cards were not available during assessments. A fifth scanning station was set up in a small side room off the main training room, also used for the echo skills assessment.

The morning included four 15-to-20-minute lectures and scanning demonstrations before each hands-on scanning session. Scanning sessions were divided into three 60-minute sessions, as shown in the timetable Figure 18.

Figure 18

Phase II Timetable

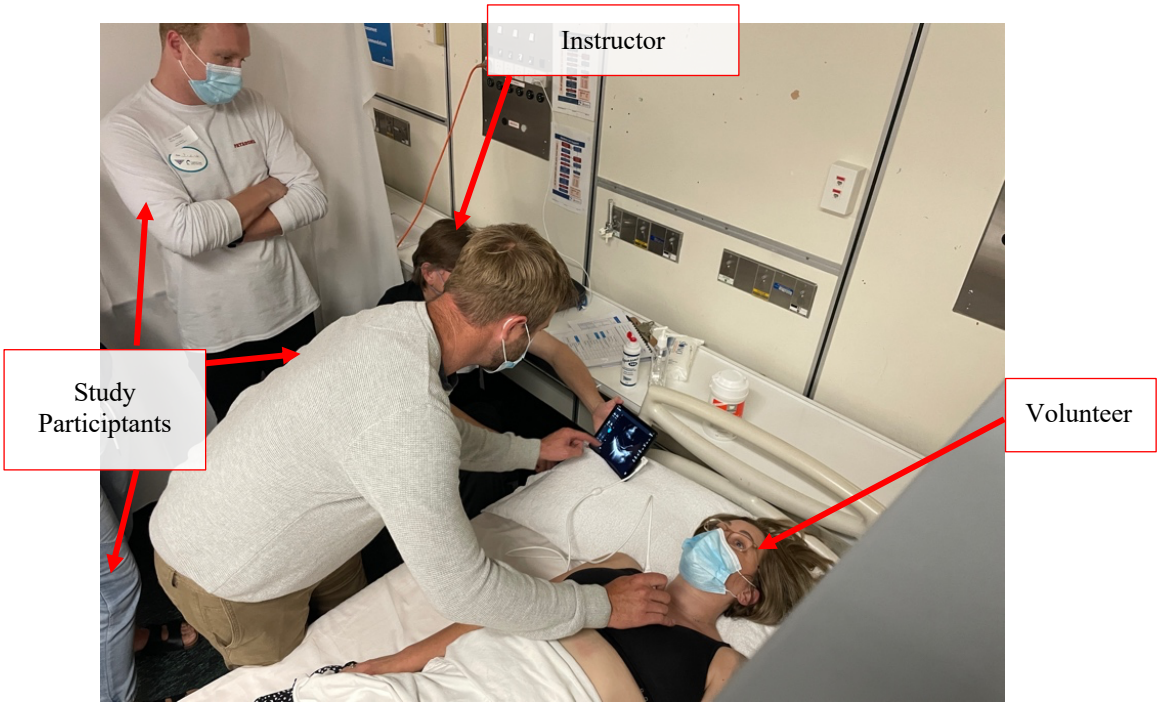
Timetable	
0830–0900	**Welcome** Introduction, Yvonne Gemmell to say a Karakia, introduction of faculty and volunteers, venue safety, orientation, group allocation for practical sessions, practical session etiquette.
0900–0920	**Lecture 1 – Demo** Echo views (SC4, A4C & PSLA) Revisit echo anatomy within each view
0920–1020	**Scanning Session 1** Familiarisation with equipment Familiarisation with transducer placement/manipulation Echo views (SC4, A4C & PSLA)
1020–1030	**Morning Tea (provided)**
1030–1045	**Lecture 2 – Image optimisation/grading system (CUSAS)**
1045–1145	**Scanning Session 2** Echo views (SC4, A4C & PSLA) Optimising images using depth, axis and gain (DAG)
1145–1200	**Lecture 3 – CAFE Exam & Reporting**
1200–1230	**Lunch (provided)**
1230–1330	**Scanning Session 3** CAFE Exam emphasis on <10-second Recording loop and reviewing images for fluid and function assessment
1330– 1345	**Lecture 4 – Cardiac arrest sim with CAFE exam demo**
1345–1400	**Afternoon Tea**
1400–1515	**Assessments (75mins)** Knowledge test Echo simulation Cardiac arrest Simulation 1
1515–1525	**Course Closure** Review, questions? Take-home messages, Phase III assessment centre date Encouraged to review the online e-learning package, course photo. Course closure.

Note. Phase II course timetable created by the author.

Each study participant, healthy volunteer and instructor assessor was pre-assigned to a scanning station and assessment group allocation was included on their name badge. The scanning session included five stations with rotations to improve scanning exposure to various body types. Scanning groups had a 3:1 participant-to-instructor ratio, as shown in Figure 19. Each scanning session provided an opportunity to build knowledge and hands-on experience, emphasising echo acquisition, image quality and integration into cardiac arrest.

Figure 19

Phase II Scanning Station



Note. A study participant demonstrating the parasternal long-axis view. Photo supplied by the author.

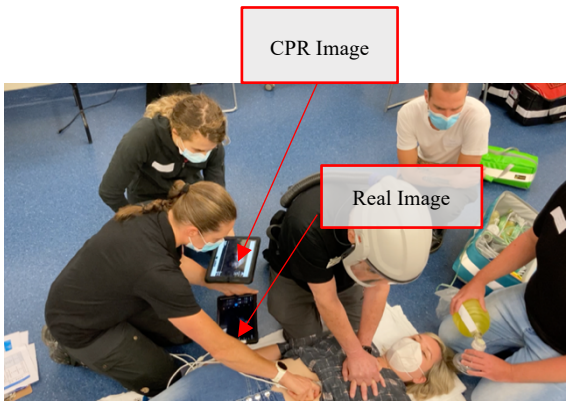
3.6.2 Simulation Orientation

Before the simulation assessments commenced, everyone (study participants, assessors, volunteers, and faculty staff) watched a short simulation demonstrating the process in lecture four. The demonstration included a 10 minute live step-by-step run-through of the simulation assessment (Figure 20). During this session, the video was stopped, and key elements such as the pulse check pause with simulated pathological scan were discussed.

Simulation volunteers and faculty staff were allocated 20 minutes to practice the simulation scenario. Before assessments commenced, each volunteer practised their role and had the opportunity to ask questions.

Figure 20

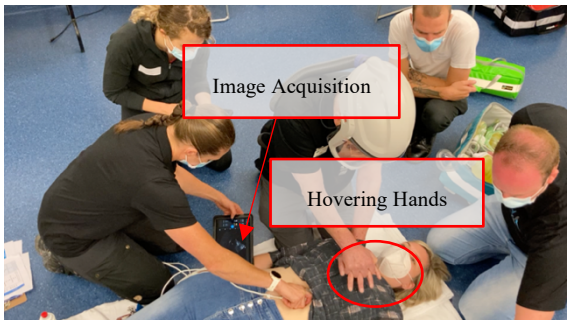
Ultrasound Simulation Assessment Imaging Sequence



Pre-imaging towards the end of the CPR cycle. The ultrasound paramedic sees the CPR ultrasound image, and a simulation scan showing CPR is placed over the ultrasound screen.



The CPR substitute scan remains in place until a few seconds before the 10 second pulse check pause.



At the 10 second pulse check pause, the CPR operator hovers above the chest. The ultrasound paramedic records an 8-second video (or less if needed), and CPR is resumed at the end of the pulse check pause dictated by the resuscitation team.



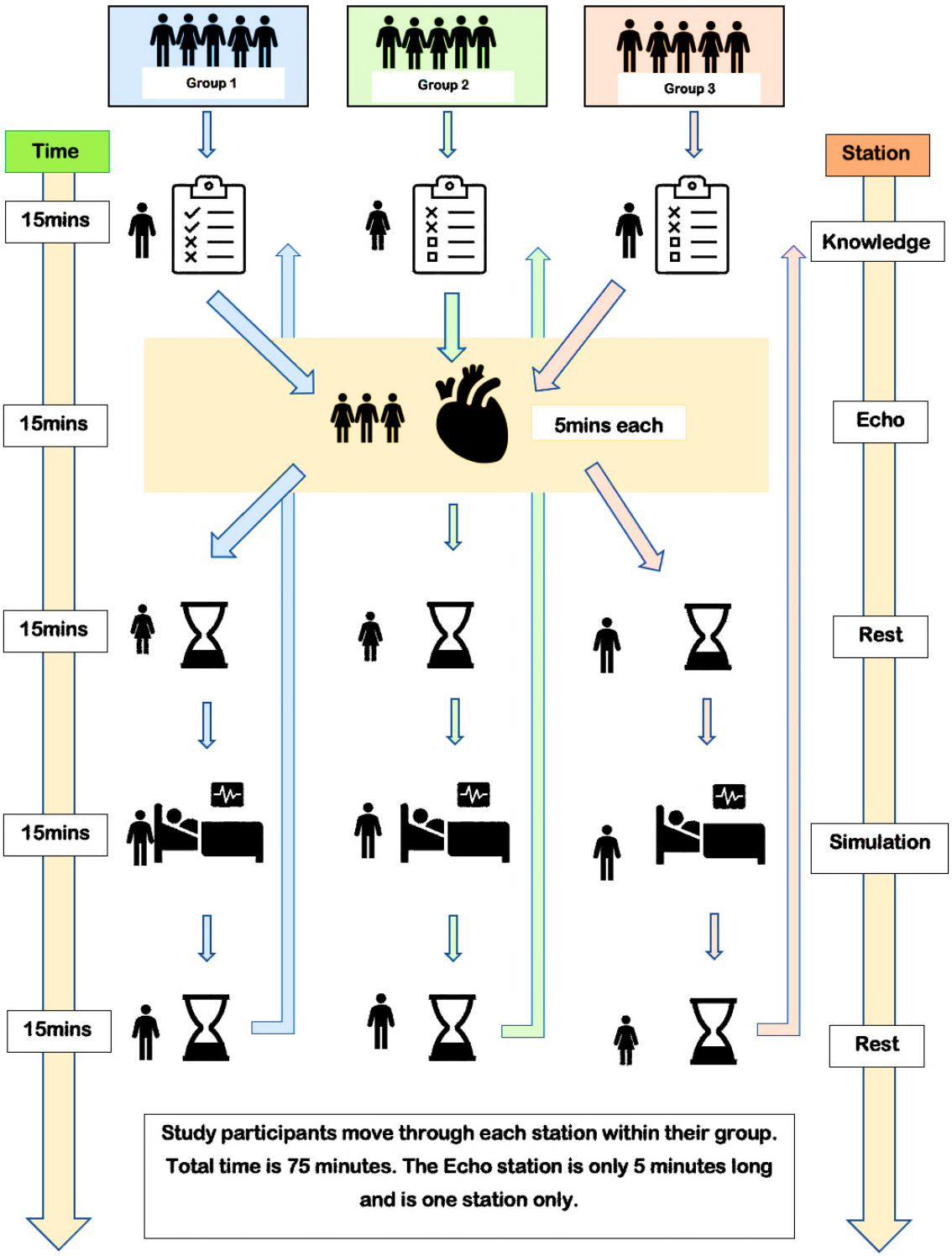
During the 2-minute CPR cycle, the ultrasound paramedic reviews a substitute pathological scan that aligns with the view they have taken and the scenario pathology.

Note. Photos supplied by faculty staff.

The assessments were scheduled in the afternoon (1400-1515 hours). Participants were divided into their pre-allocated groups. All groups commenced their assessments simultaneously, with one participant at each station. Each station was 15 minutes in duration, 75 minutes in total. The echo station was 5 minutes per participant totalling 15 minutes for the rotation. Two rest stations were added to improve the assessment process flow and allow time between assessments to reduce stress and fatigue. The flow diagram shown Figure 21 depicts assessment of the participants.

Figure 21

Phase II Assessment Flow Diagram



Note. The left arrow (green box) shows the time, and the right-hand arrow (orange box) shows the station. Groups one, two and three move through each station until all stations are complete.

3.6.3 Knowledge Quiz Equipment

The equipment for the knowledge quiz station included four laptops, two Apple® MacBooks and two Hewlett Packard® PCs. The two Apple® laptops had a touchpad mouse, and the others had an auxiliary mouse.

3.6.4 Knowledge Quiz Description

The online Canvas knowledge quiz was built into the eLearning Canvas platform and was accessible to the study participants during the assessment. The quiz was designed to test theoretical knowledge of heart sonographic anatomy, echo view identification and pathology relevant to PEA cardiac arrest. The knowledge quiz also answered the research question: Can paramedics adequately identify the presence of pseudo-PEA, true PEA, and cardiac tamponade?

The quiz consisted of 12 multiple-choice questions (MCQ) with an inbuilt 15-minute time limit initiated by the participant at the commencement of the quiz. Once this time was complete, the quiz would automatically end. The quiz used a variety of MCQ and dropdown menu answer styles. Settings within the quiz allowed participants to progress forwards with no option to review questions before submitting the final answers. The quiz questions were not randomised with no quiz item bank used. Study participants had no prior knowledge of this information.

At the time of assessment, participants were shown to a private room or quiet area with access to a computer. An invigilator Dr. Andy Swain (AS) was present to assist with the login process and technical support. Web browsers were set to a Google® Chrome incognito page and loaded with the Canvas login. Study participants were asked to log in using their study identification number and password. If the participant forgot their credentials, the

invigilator had access to a master copy of usernames and passwords. This next section outlines each quiz question in detail.

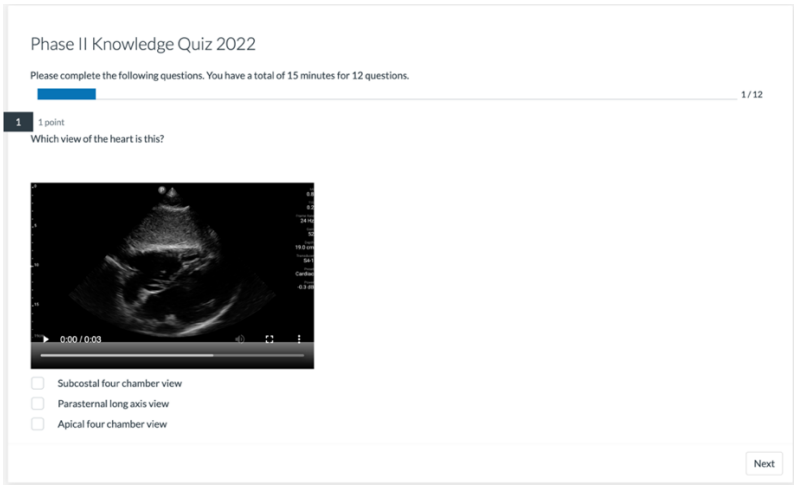
Quiz Question One. Participants were asked to identify which echo view was shown in a 3-second video clip shown in Figure 22. This clip could be paused and replayed. Multichoice options included:

- Subcostal four chamber view
- Parasternal long axis view
- Apical four chamber view

The correct answer is the SC4 view. The purpose of this question was to test echo view identification. This question is awarded one point for the correct answer. The term subcostal also known as subxiphoid was used in error which may have caused some confusion for this question.

Figure 22

Knowledge Quiz Question One



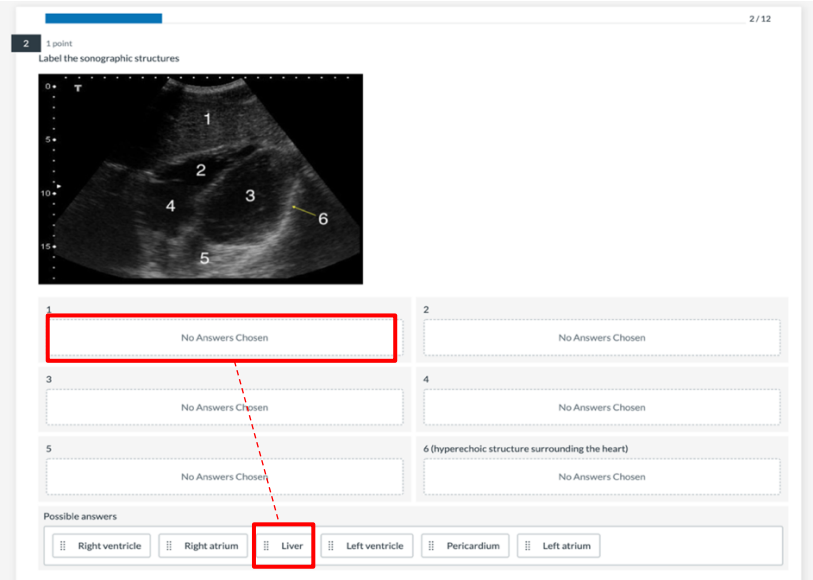
Note. The author took a screen capture.

Quiz Question Two. This question displayed a static ultrasound image of a SC4 view which highlighted fundamental anatomical structures numbered one to six. This question required participants to drag and drop six possible answers into the correct box shown in Figure 23. Available answers included the right ventricle, right atrium, liver, left ventricle, pericardium, and left atrium. This question assessed anatomical knowledge which is relevant to evaluating the presence of fluid (pericardial effusion) and contractile function (squeeze) of the left ventricle. This question was awarded one point. An incorrect answer was awarded no points. The correct answers were:

1. Liver
2. Right ventricle
3. Left ventricle
4. Right atrium
5. Left atrium
6. Pericardium

Figure 23

Knowledge Quiz Question Two



Note. The red box outlines the drag-and-drop options—a screen capture taken by the author.

Quiz Question Three. A coloured and numbered still echo image of the parasternal long-axis view was used. Similar to question two, vital anatomical structures were numbered from one to five with the addition of coloured anatomical structures. The coloured anatomical structures included the pericardium, left ventricular septum, lateral wall, and mitral valve. The numbers corresponded with the right ventricular aortic outflow tract, left atrium, left ventricle and descending aorta. The question required participants to click a dropdown menu and select from eight possible answers shown in Figure 24. This question was awarded one point. One incorrect answer awarded no points. The correct answer is:

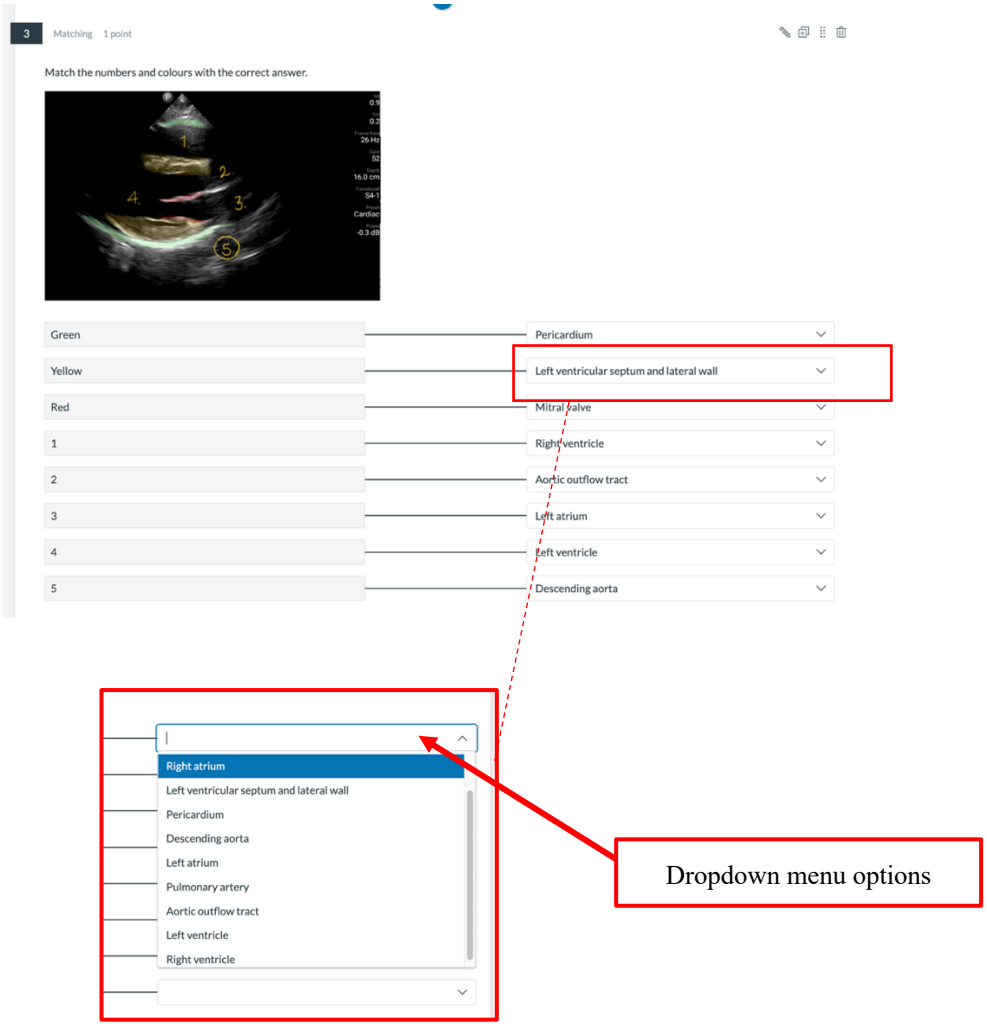
1. Right ventricle
2. Aortic outflow tract
3. Left atrium
4. Left ventricle

5. Descending aorta

- Pericardium (green highlight)
- Left ventricular septum and lateral wall (yellow highlight)
- Mitral valve (red highlight)

Figure 24

Knowledge Quiz Question Three

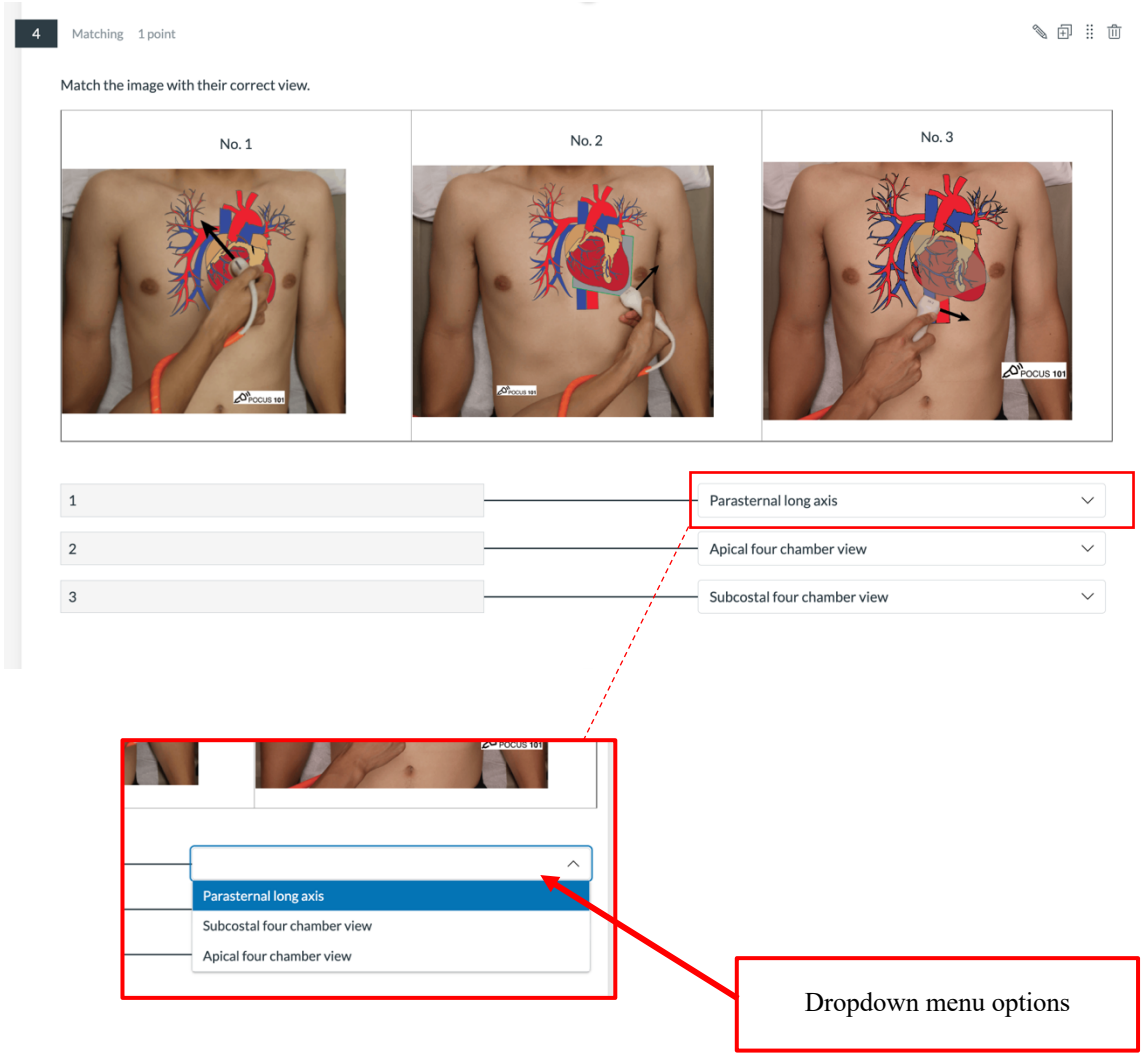


Note. The author took a screen capture.

Quiz Question Four. This was based on an illustration of the three echo views taught in this study. The three views included the PSLA, A4C and the SC4 view. This question required participants to click a dropdown menu beside each box and select the correct answer as shown in Figure 25. This question aims to test the knowledge of the physical probe position used to achieve each echo view. The correct answer is 1) parasternal long axis, 2) apical four chamber view, 3) subcostal four chamber view.

Figure 25

Knowledge Quiz Question Four

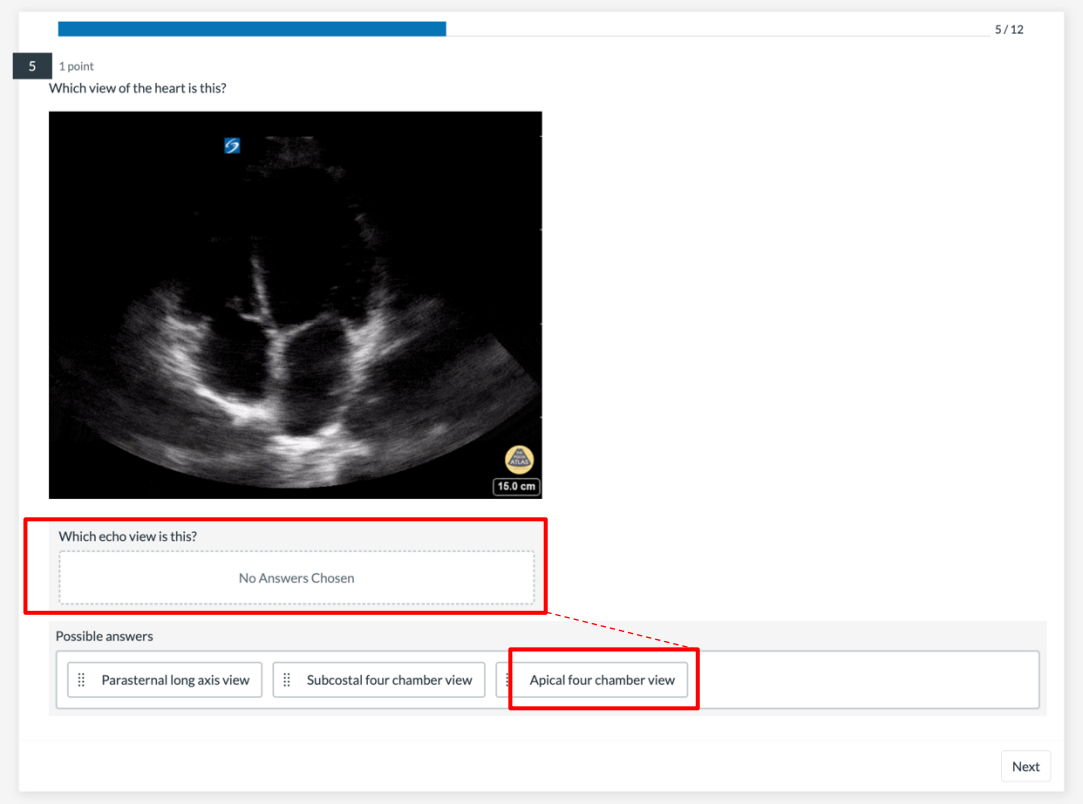


Note. The author took a screen capture.

Quiz Question Five. This question presented a GIF (Graphics Interchange Format, a constantly moving image that cannot be paused or rewound) echo image of an A4C scan. The three possible answers included the PSLA, A4C and the SC4 view. This question required participants to drag and drop their answers into the box shown in Figure 26. This question aimed to test the knowledge of the echo views used in this study. The correct answer is the A4C view.

Figure 26

Knowledge Quiz Question Five



Note. Red box outlining drag and drop from possible answers tab to box one. The author took the screen capture.

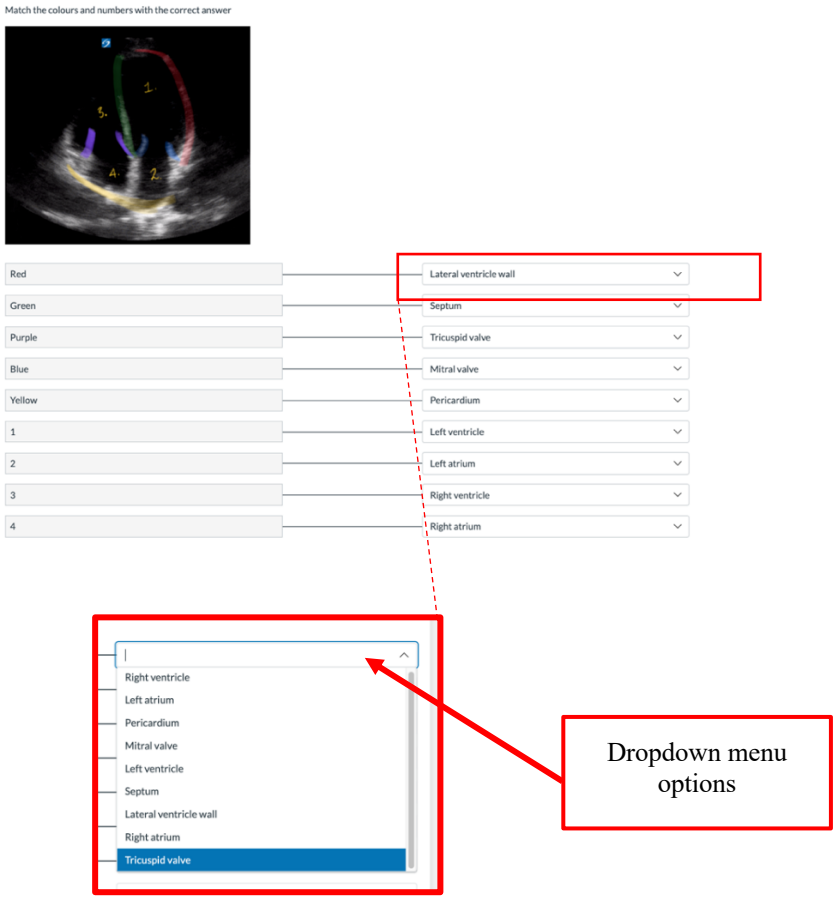
Quiz Question Six. A coloured and numbered still echo image of the A4C view was displayed. Similar to question three, vital anatomical structures are numbered from one to four with the addition of coloured anatomical structures. The coloured anatomical structures included the lateral ventricle wall, septum, tricuspid valve, mitral valve, and pericardium. The numbered regions corresponded with the left and right ventricles and the left and right atrium. The question asked participants to click a dropdown menu and select from eight possible answers as shown in Figure 27. This question was awarded one point. One wrong answer awarded no points. The correct answer is:

1. Left ventricle
2. Left atrium
3. Right ventricle
4. Right atrium

- Lateral ventricle wall (red highlight)
- Septum (green highlight)
- Tricuspid valve (purple highlight)
- Mitral valve (blue highlight)
- Pericardium (yellow highlight)

Figure 27

Knowledge Quiz Question Six



Note. Screen capture supplied by the author.

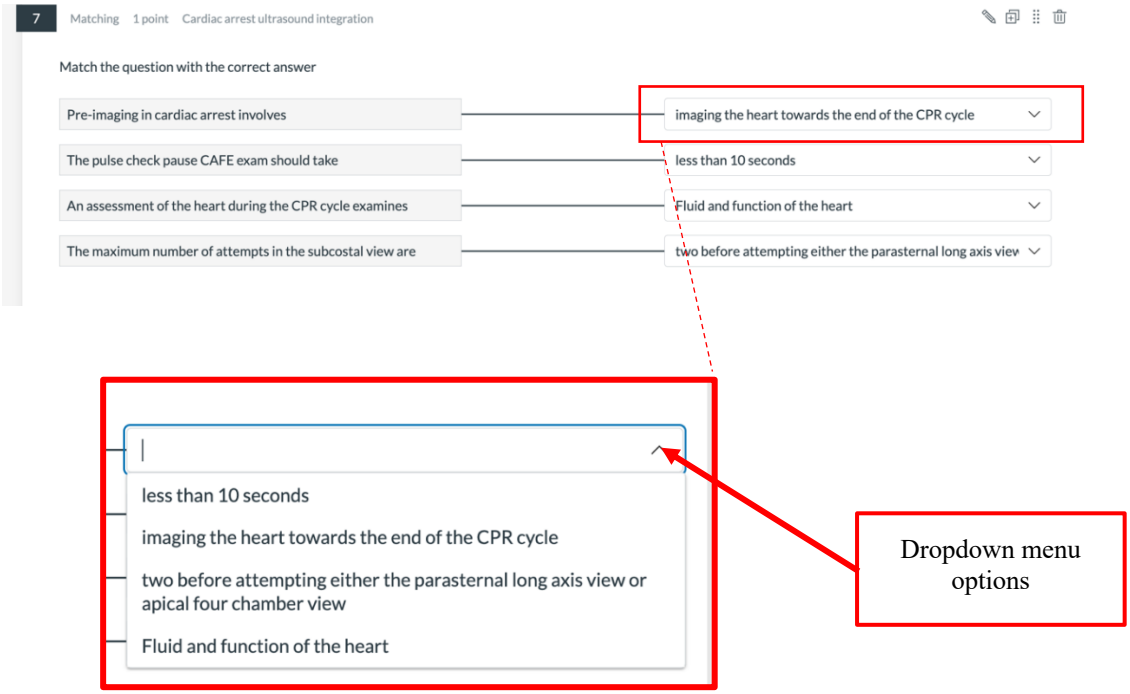
Quiz Question Seven. This question asked the participant to match the question with the correct answer to complete the sentence using a dropdown menu shown in Figure 28. The four sub-questions focused on integrating ultrasound into cardiac arrest using the CAFE exam. This question was awarded one point. The correct answers are shown below:

- Pre-imaging involves? *imaging the heart towards the end of the CPR cycle.*
- The pulse check pause CAFE exam should take? *less than 10 seconds.*

- An assessment of the heart during the CPR cycle examines? *fluid and function of the heart.*
- The maximum number of attempts in the SC4 view is? *two before attempting either the parasternal long axis view or the apical four chamber view.*

Figure 28

Knowledge Quiz Question Seven

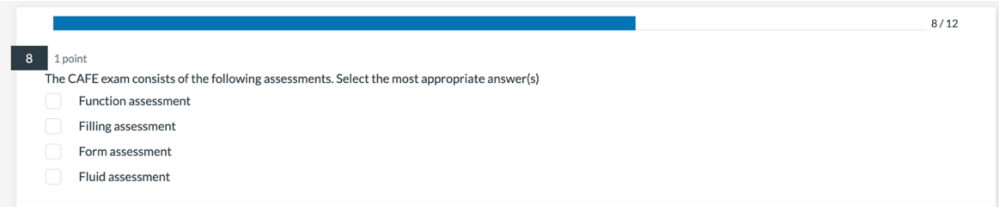


Note. Screen capture supplied by the author.

Quiz Question Eight. This question asked participants to select the assessments associated with the CAFE exam shown in Figure 29. This question aims to evaluate the knowledge of CAFE exam assessments. This question was awarded one point. The correct answer is fluid and function assessment.

Figure 29

Knowledge Quiz Question Eight

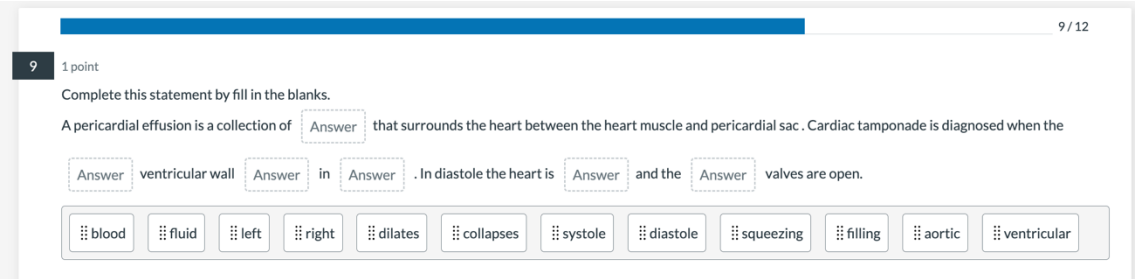


Note. Screen capture supplied by the author.

Quiz Question Nine. This question asked participants to complete the sentence by filling in the blank spaces shown in Figure 30. The question tests knowledge of tamponade physiology. Correct answers are in italics. The sentence with correct answers included: "A pericardial effusion is a collection of *(fluid)* that surrounds the heart between the heart muscle and the pericardial sac. Cardiac tamponade is diagnosed when the *(right)* ventricular wall *(collapses)* in *(diastole).* The heart is *(filling)* in diastole, and the *(ventricular)* valves are open". Answers were dragged into the available spaces to complete the sentence. This question was awarded 0.16 points per answer with six correct answers awarded one full point. Partial points were awarded per correct answer.

Figure 30

Knowledge Quiz Question Nine

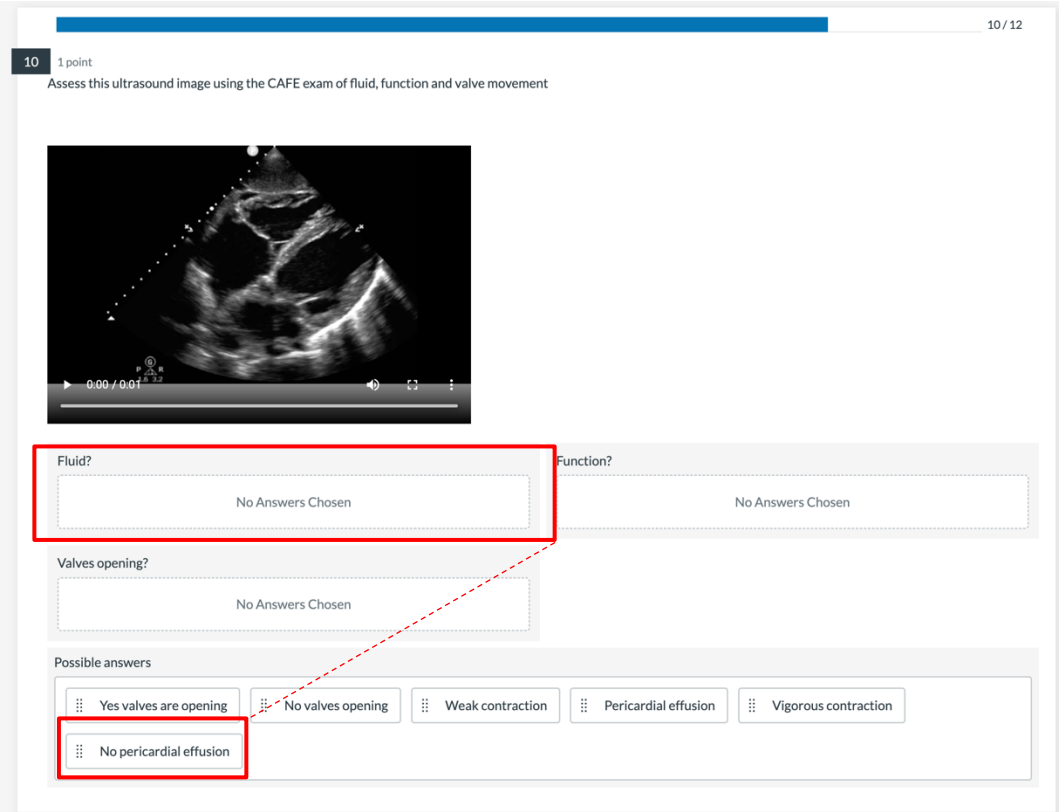


Note. Screen capture supplied by the author.

Quiz Question Ten. This question asked participants to review the video clip and evaluate the image using the CAFE exam shown in Figure 31. This clip could be paused and replayed. The question aimed to assess the participants' ability to determine the presence or absence of a pericardial effusion (fluid), left ventricular squeeze (function) and the presence or absence of valvular movement. This question was awarded one point. The correct answer is no pericardial effusion, weak contraction and valves are opening.

Figure 31

Knowledge Quiz Question Ten



Note. Screen capture supplied by the author.

Quiz Question Eleven. As shown in Figure 32, this question asked participants to determine the likely diagnosis of a 75-year-old male who has experienced chest pain over the past 24 hours. He collapsed while making breakfast and is in a PEA cardiac arrest. The participant performed the CAFE exam and saw the GIF ultrasound image shown. The question asked was "What is the likely diagnosis?". The correct answer was pericardial effusion causing tamponade. Available answers included:

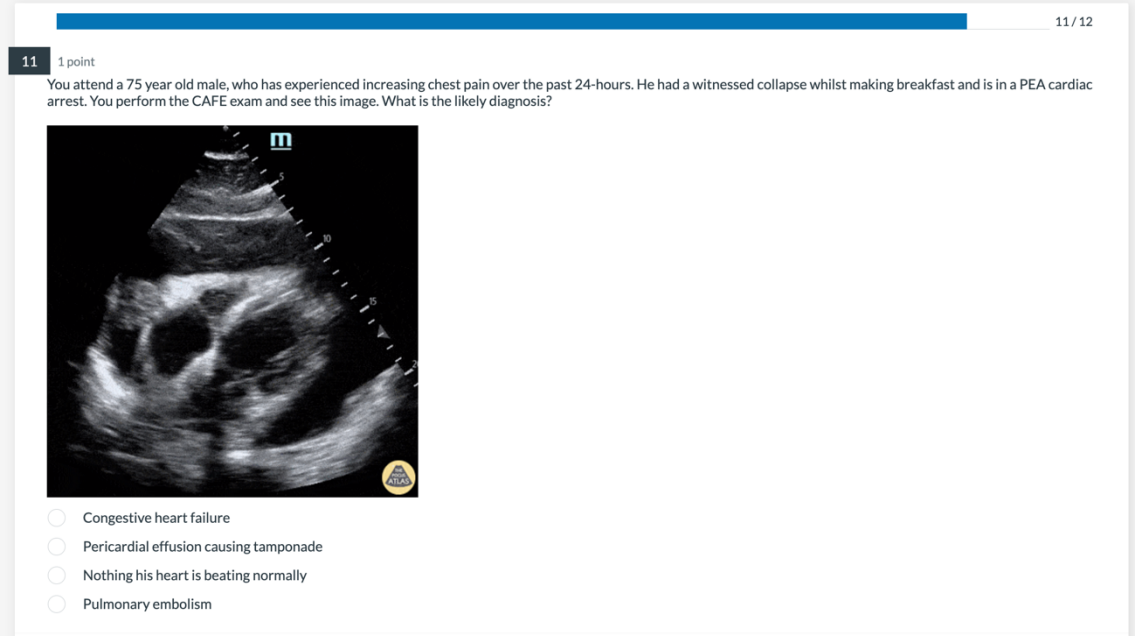
- Congestive heart failure
- Nothing - this heart beats normally

- Pulmonary embolism.

This question aimed to demonstrate a realistic scenario of a PEA cardiac arrest with potentially reversible pathology. The question was awarded one point. The correct answer is pericardial effusion causing tamponade.

Figure 32

Knowledge Quiz Question Eleven



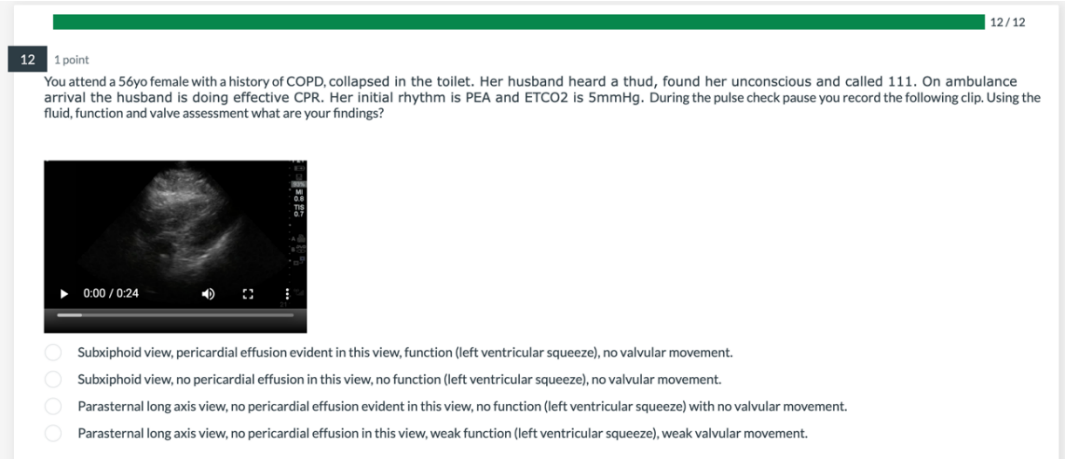
Note. Screen capture supplied by the author.

Quiz Question Twelve. As shown in Figure 33 this question presented a PEA cardiac arrest scenario of a 56-year-old female with a history of COPD who collapsed in the toilet. Her husband heard a thud, found her unconscious and called 111. On ambulance arrival, the husband was doing effective CPR. Her initial rhythm was PEA and $ETCO_2$ reading of 5 mmHg. During the pulse check, the following clip was recorded. Using the fluid and function

and valve assessment, the question asked was “What are your findings?”. The ultrasound video clip could be paused and replayed as needed. This question assessed the participants’ interpretation of an asystole ultrasound image without pericardial effusion or movement. This question was awarded one point. The correct answer is subcostal view, no pericardial effusion, no function, and no valvular movement.

Figure 33

Knowledge Quiz Question Twelve



Note. Screen capture supplied by the author.

3.6.5 Simulation Environment Limitations

The limitations of the simulation for this study included the actors, simulation fidelity and preparing the participant for the scenario. An example of the simulation environment is shown in Figure 34.

Figure 34

Simulation Assessment Stations Wellington Simulation Suite

Station 1 Station 2 Station 3



Note. Photos supplied by the author.

3.6.6 Simulation Equipment

The WFA training department provided the simulation equipment managed by their Paramedic Educator Brendan Harris. Brendan organised the equipment and simulation staff (healthy volunteers, assessors, and faculty). The Corpuls® defibrillation trainer and medical equipment used during simulations were familiar to the ambulance staff and are used operationally. Each ultrasound scanning station was equipped with a Koninklijke Philips N.V Lumify® handheld ultrasound device (Samsung® android tablet) and probe (cardiac) pictured in Figure 35. Three Lumify units were supplied by Philips® New Zealand, and two additional units from borrowed from Wellington ED. Many factors influence ultrasound image quality, including imaging equipment and familiarity, user skill and unfavourable imaging conditions generated by patient habitus and environment. When diagnosis relies on the quality of the ultrasound image, the equipment is of utmost importance. A recent study by Le et al. (2022) compared four handheld POCUS devices highlighting the good image quality of the Philips®

Lumify when compared with other handheld devices (Butterfly® IQ+, Kosmos®and GE® Vscan Air). Paramedics in the CAFE study used the Philips® Lumify ultrasound device, which demonstrated the best image quality, contrast resolution, and overall image satisfaction in a study by Le et al. (2022) highlighting favourable performance of Lumify in the POCUS setting.

Figure 35

Philips® Lumify Tablet and Cardiac Probe



Note. Product Image from *Medical Dealer*, n.d. (https://medicaldealer.com/philips-lumify/).

3.6.7 The Assessor Role

The assessor's role is to mentor practical learning in phase II and assess in phase II and III. Assessments are marked against the CAFE study specific rubric. Competencies were marked as either 'competent' or 'not yet competent'. This was to streamline assessments given the brief educational and hands-on components, and to facilitate ease of marking by

multiple assessors across phases II and III. An example of a simulation assessment rubrics for phases II and III are shown in Appendix O. Assessor feedback was encouraged; however, no "coaching" was provided during the active simulation assessments and echo acquisition. Competencies were marked as either 'competent' or 'not yet competent'. Results were documented and discussed with the participant on completion of the assessment.

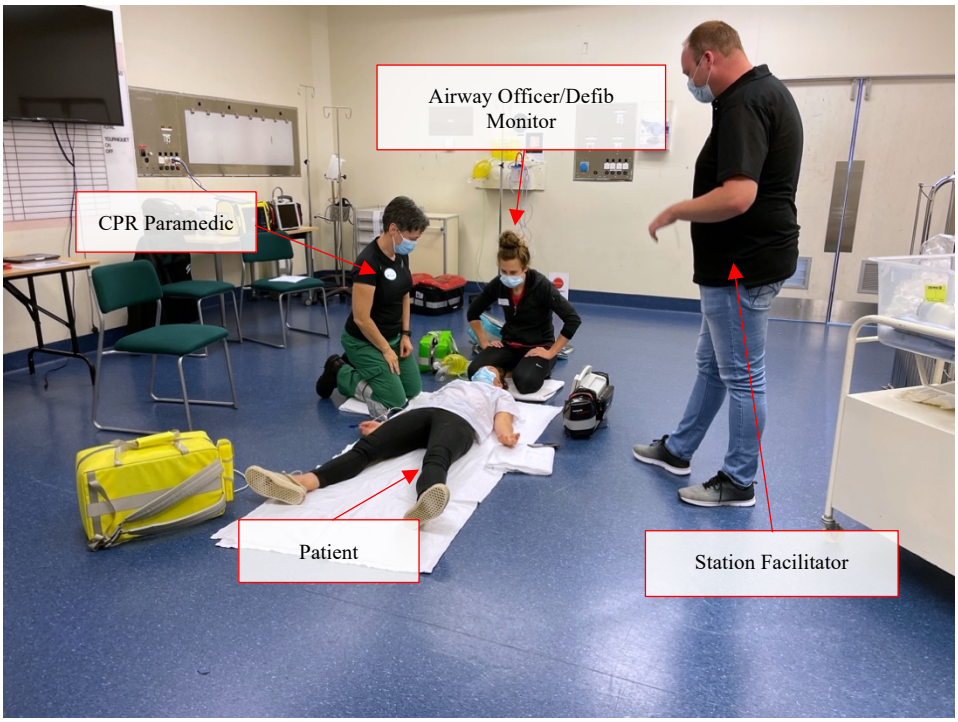
3.6.8 Simulation Assessments (15 minutes)

Simulation assessments were used to demonstrate competence in ultrasound use in cardiac arrest whilst exhibiting a working knowledge of the ultrasound equipment, image acquisition, problem-solving and image interpretation. The CAFE simulations were allocated 15 minutes per simulation; 10 minutes of live simulation and 5 minutes for assessor and participant debriefing. During CPR, the participant was asked to evaluate the ultrasound video and record their findings on the CAFE form. Each simulation generated three images from three pulse check pause periods. Hands-off time was measured in seconds and recorded by the assessor.

Each scenario involved five members (one assessor, two paramedics and one patient), shown in Figure 36. The assessor examined the study participant using an OSAUS assessment form.

Figure 36

Simulation Roles



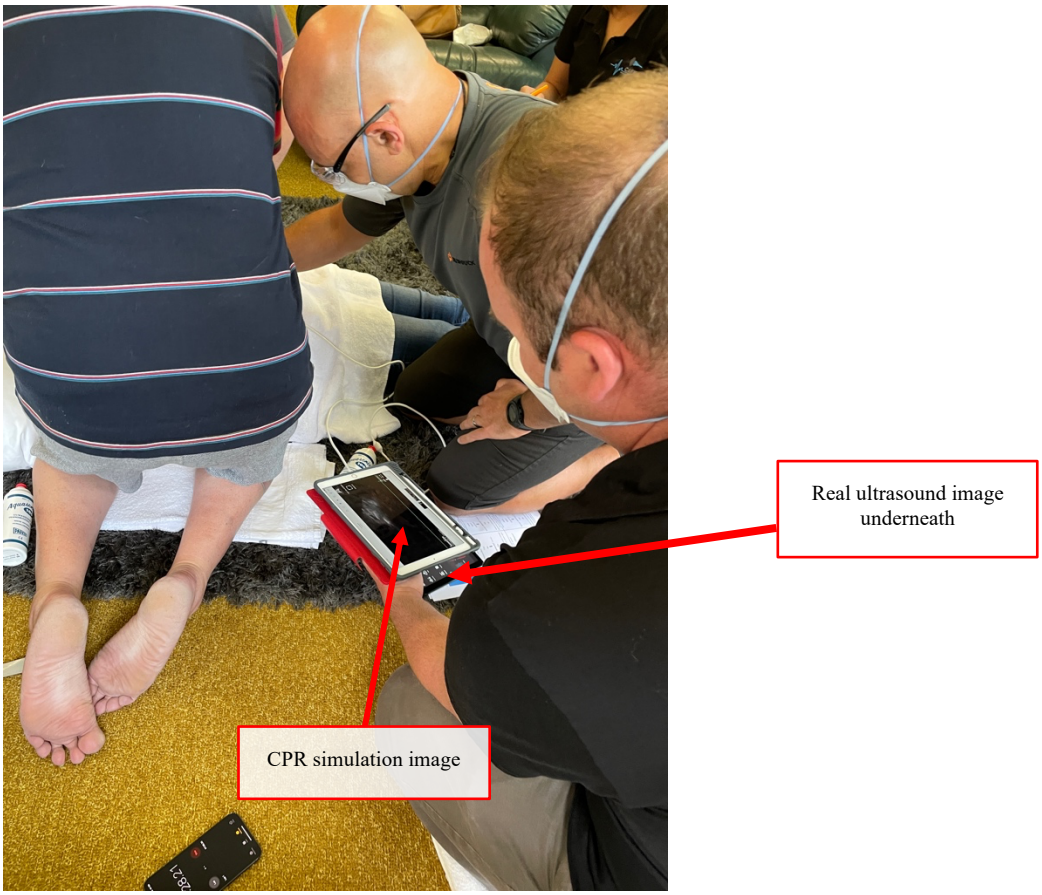
Note. Photo supplied by the author.

3.6.9 Pre-Imaging Technique

Pre-imaging captures an echo image of the heart during CPR with the aim of reducing the time taken to acquire an image during the 10 second pulse check pause. An ultrasound probe is placed in the SC4 view during CPR towards the end of the 2-minute cycle. For this study the real-time ultrasound image captured by the participant during pre-imaging was covered by a second tablet which displayed a 34 second video clip of a heart during CPR as shown in Figure 37.

Figure 37

Pre-imaging Simulation CPR



Note. Photo supplied by the author.

The rationale for concealing the real-time ultrasound video was to improve the validity of the time taken to acquire an echo image during the pulse check pause. The simulation tablet was removed when CPR stopped, allowing the participant to acquire a real-time ultrasound image. During the pause, the participant presses record on the ultrasound device, optimises the image, and removes the probe 10 seconds later. The ultrasound video record time was set for 8 seconds with an audible beep to indicate the recording had finished. The CPR paramedic was instructed to hover above the chest, ready to commence CPR as

soon as the 10 seconds were finished. If the ultrasound was completed before the 10 seconds, the CPR paramedic was instructed to recommence CPR.

Study participants were encouraged to commence scanning in the SC4 view as this is the least interruptive and most accessible for pre-imaging before the pulse check pause starts, as shown in Figure 38. However, if the study participant could not achieve an image in this view after two attempts, they were advised to move to other views, including the A4C or PSLA view.

Figure 38

Simulation Image Acquisition Subcostal View



Note. Photo supplied by the author.

3.6.10 CAFE Exam Interpretation

Participants were given a PEA cardiac arrest pathological scan to interpret during the 2-minute CPR interval between pulse checks. This evaluation occurred following the completion of the ultrasound examination during the simulated pause in CPR (Figure 39).

Figure 39

Simulation Image Analysis During CPR Cycle



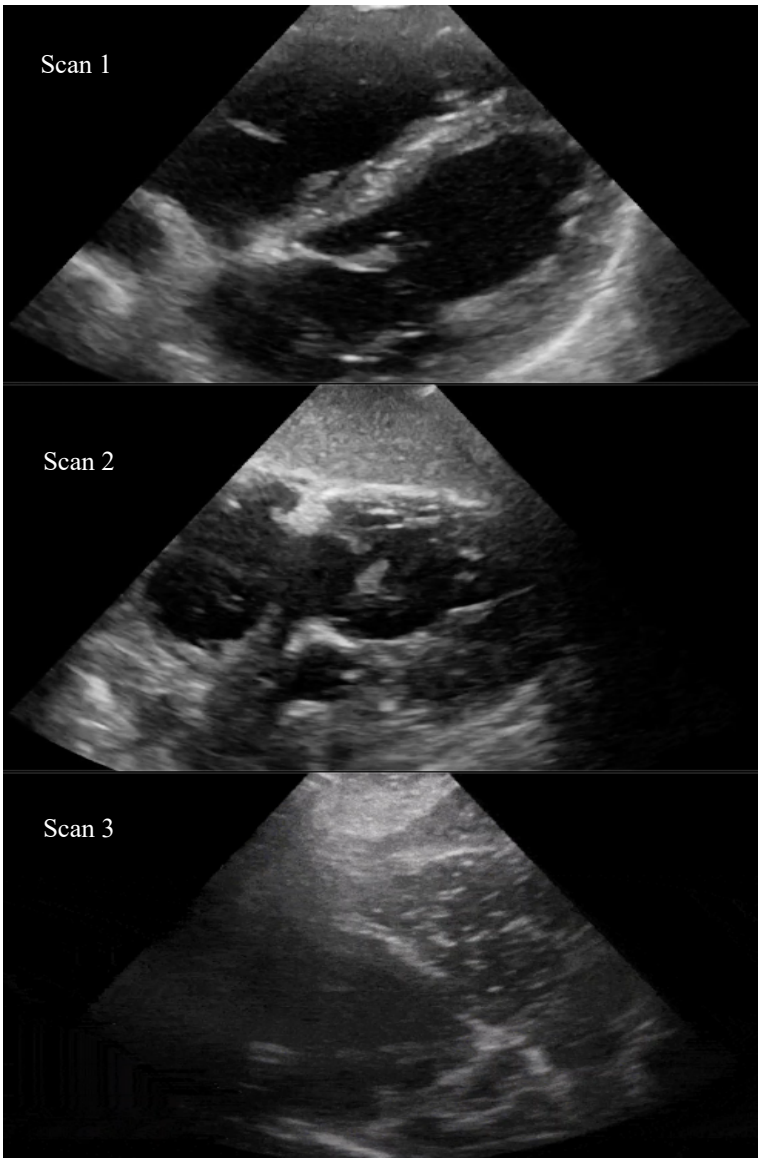
Note. Photo supplied by the author.

The aim was to use the CAFE exam form to document image interpretation. The CAFE form included a 'fluid' evaluation for the presence of pericardial effusion and evidence of tamponade, as well as a 'function' evaluation to classify ventricular squeeze as none, weak, or vigorous. Of note, the simulation scan series did not show pathology for pericardial effusion or tamponade. This pathology was assessed within the knowledge quiz.

Finally, valvular movement was a measure of forward blood flow through the heart. The pathological scan set presented to participants during simulations were intended to track the progression of a pseudo-PEA cardiac arrest to true PEA. The scan series included three pathological images per echo view, one for 2-minute round of CPR. The first image for each echo view was relatively straightforward with distinguishable anatomical structures such as the pericardium, septum, and valves of the heart. As the simulated cardiac arrest progressed, the heart condition was programmed to deteriorate, resulting in the final simulated image of true PEA, as shown in the static images illustrated in Figure 40.

Figure 40

Pathological Subcostal Scan Series



Note. Subcostal view scan series for the cardiac arrest simulation. Screen capture supplied by the author.

Simulation scans were set on a video loop which could be paused and scrolled through as needed by the study participant. The scan series shown to the study participant was time-dependent, meaning if the participant was up to their third scan within the cardiac arrest simulation, they were shown the third scan in the simulation scan series. Each

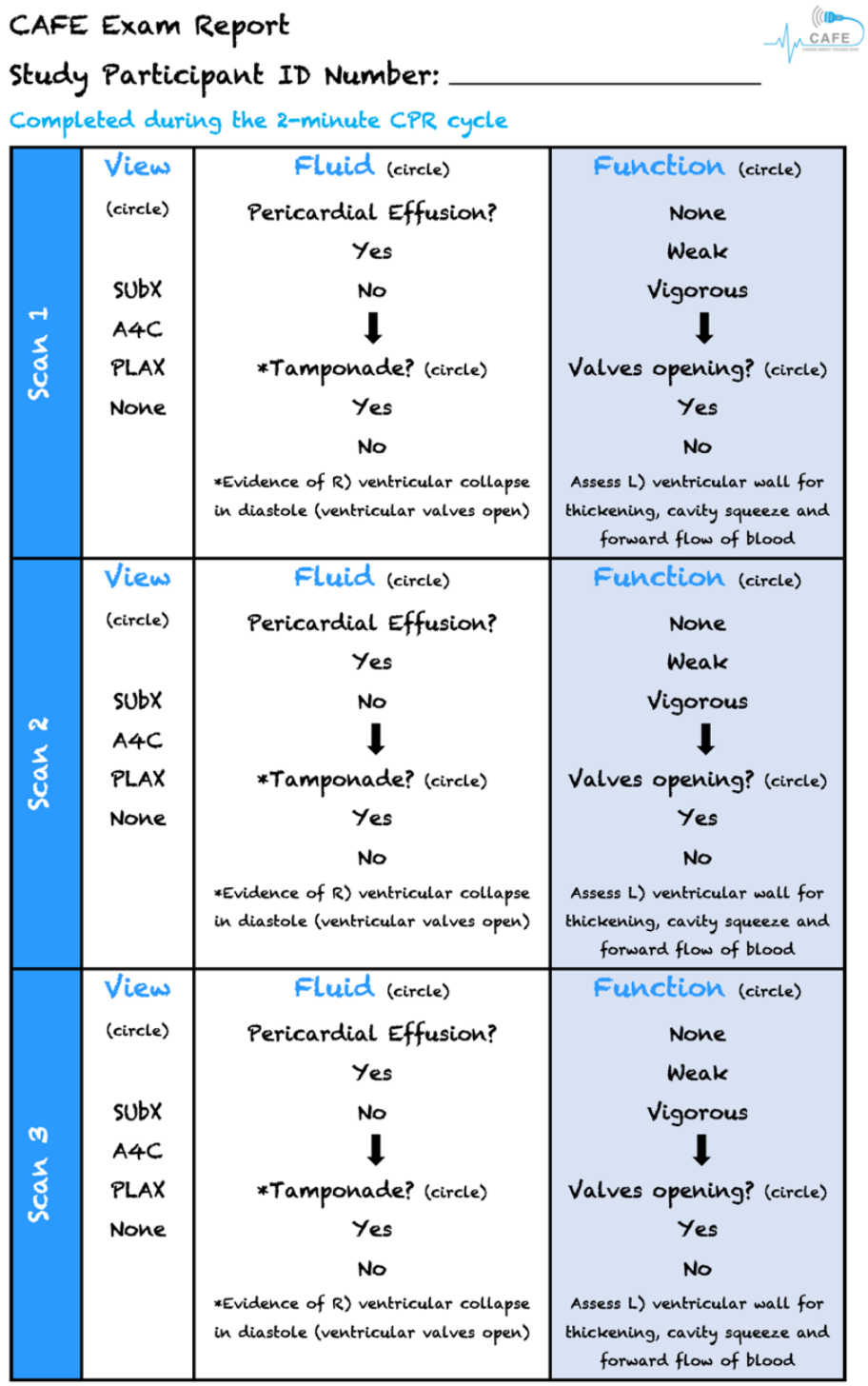
participant is offered the same set of scans between phases and stations for consistency. Once the study participant had reviewed the scan, they completed a CAFE Exam report form shown in Figure 41.

CAFE Report Form. The CAFE exam assessed the 'Fluid and Function' of the heart. Participants circled their interpretation of the pathological simulation image, assessing for pericardial effusion or tamponade, the heart's function (none, weak or vigorous) and whether the valves were opening. When the simulation was complete, the ultrasound study was ended and saved to an internal storage card.

The study also assessed competencies beyond the original research questions. Assessors used manual marking sheets during practical assessments of simulations and echo stations referenced in Appendix O and P. The assessment included the participants competence level by ticking a corresponding box with data categorised as 'competent' or 'not yet competent'.

Figure 41

CAFE Exam Participant Report Form for HOT Simulations



Note. Screen capture supplied by the author.

3.6.11 Echo Skills Station Assessment

The rationale for this assessment was to assess echo imaging acquisition and real-time interpretation without the pressure of a cardiac arrest scenario. Participants were asked to demonstrate all three echo views and point out sonographic anatomy on the ultrasound tablet screen. This assessment lasted 5 minutes, and the assessor marked against the OSAUS rubric which is available in Appendix P. Figure 42 shows an echo station exam during an assessment in phase III.

Figure 42

Group A Phase III Echo Assessment



Note. Photo supplied by the author.

3.6.12 Refresher Training Module

The author developed a 30-minute refresher module for participants to view on Canvas between phase II and III. The supervisor (AS) reviewed the refresher module on February 17, 2022. Group A study participants were emailed a 'Refresher Opportunity' on March 6th, 2022, and group B, on June 6th, 2022, they were advised that an optional refresher module was available. The refresher course was accessed by 11 participants from group A and 14 from group B.

The refresher content included one 3-minute narrated video demonstrating the three echo views. The second video included a 25-minute video discussing learning points from phase II and highlighting the importance of adhering to the 10 second pulse check pause. Refresher topics included:

- Cardiac arrest integration and the simulation process
- Pre-imaging and the process of the simulation substitute pathological scan
- Equipment familiarity with particular attention to the save loop touchscreen button
- CAFE exam report form familiarity
- Pericardial effusion and tamponade physiology
- Image review and sonographic anatomy
- Summary and the importance of the 10 second pulse check pause adherence
- A discussion of the simulation process

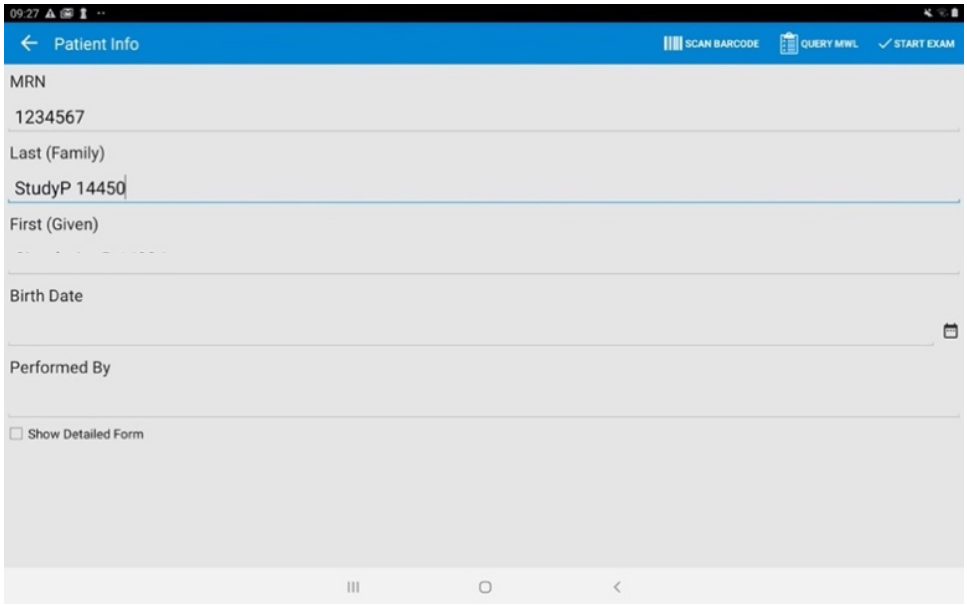
3.6.13 Ultrasound Images Data Entry

Ultrasound images were automatically assigned a Medical Record Number (MRN) generated by the ultrasound device. Study participants entered their study ID and assessment station numbers into the patient information section (Figure 43). This data allowed the

matching of images with study ID and retrospective review of the images. Missing images resulted from participant error failing to record or store the image. Missing images were treated as missing data and included as missing in frequency tables. Missing ultrasound images reviewed by Rater A and B were excluded pairwise for inter-rater reliability analysis.

Figure 43

Ultrasound Study Identification Data Entry



Note. Screen capture supplied by the author. MRN = Medical Reference Number, StudyP = Study Participant.

3.6.14 Data Storage

All data was stored on the AUT OneDrive server, accessible by authorisation only. Access was available for the author, supervisors Dr. Bronwyn Tunnage, Dr. Andy Swain and Dr. Nick Garrett, the statistical advisor. Hard copies of the assessment sheets, echo assessment, simulation assessment, CAFE report form, and the Secure Digital (SD) card,

were stored at Life Flight Wellington. Data collected from these for analysis was stored on the AUT OneDrive. Study ultrasound videos taken in phases II and III were stored in two places; firstly, on the ultrasound tablet's internal storage and on a removable memory card downloaded to AUT OneDrive. Data collection commenced after the completion of phase I group A. After completing this for each group, data was entered into into IBM® Statistical Package for Social Sciences (SPSS®) for Apple® Mac, version 29.0.0.0 (241).

3.7 Phase III Design

Assessment Centre. For this study, participants who achieved a pass mark of ≥ 80% in the knowledge quiz during phase II were eligible to progress to phase III. However, participants who did not meet this threshold and failed the phase II assessment were required to complete the refresher module to address knowledge gaps and enhance their skills. Successful completion of the refresher module was a prerequisite for participation in phase III, ensuring that all participants had the opportunity to reinforce their learning and improve their readiness for the subsequent assessment. There was a 4-week gap between phases II and III, facilitating knowledge consolidation and ensuring participants-maintained work-life balance. While the assessments in phase III mirrored phase II, an additional simulation was incorporated to enrich the data set. Participants underwent two simulation assessments on the day including an echo skills assessment and a knowledge quiz (same questions as in phase II quiz). Each segment was allocated 15 minutes, with a 5-minute transition period between them. Audible signals indicated the start and end times and the changeover moments. An example of the assessment station environment can be seen in Figure 44. To maintain assessment fairness, privacy screens separated stations, and participants were instructed to maintain confidentiality about the assessment content. Detailed descriptions of the simulation and echo setups were given in phase II.

Venue Change. Due to the pandemic's implications, the Wellington Simulation Suite cancelled all reservations. Consequently, the assessment day was hastily relocated to the Salvation Army Church Hall on 177 Main Road, Tawa, Wellington. This was the sole available alternative shown in Figure 44. Group B's phase II took place on May 27th, 2022, spanning from 0830 hours to 1525 hours. All involved parties, including faculty, volunteers, and participants, were promptly informed of the venue shift via email or phone. While the Salvation Army Tawa Church Hall sufficed with adequate facilities and neighbouring simulation rooms, this sudden location change, though necessary during the pandemic, introduced some disruption.

Figure 44

Salvation Army Church Simulation Environment



Note. Photo supplied by the author.

The main hall was converted into a classroom with chairs in the centre and scanning stations on the side. Each scanning station was equipped with the same equipment as previously stated. Privacy was maintained using makeshift sheet partitions and portable massage tables as beds. The scanning stations doubled as quiz stations, with partitions providing privacy. Photos of the Wellington and Tawa research days are available in

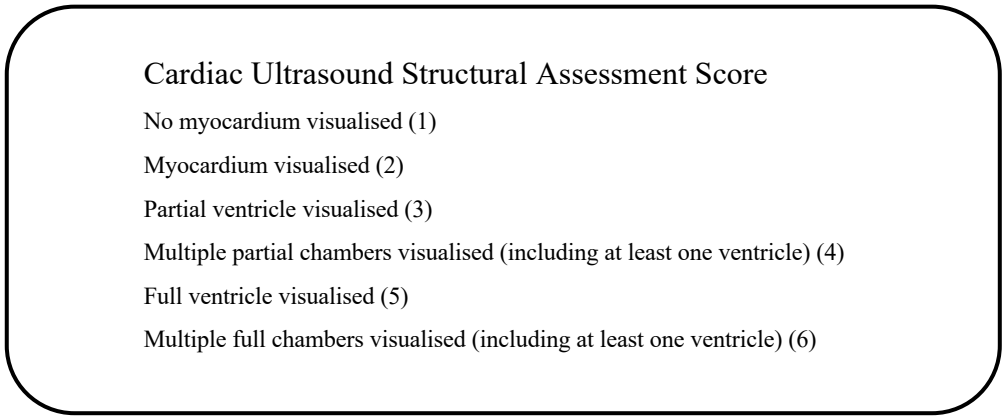
Appendix Q. The uncertainty of the pandemic resulted in the remaining phases running at the church. Group B phase III was held at the Tawa Salvation Army Church on June 20th, 2022.

3.7.1 External Reviewing Process

External reviewers A and B were contacted by email. The author uploaded study ultrasound video clips to a Google ® Drive account, where reviewers were invited to view images. Reviewers were sent a Microsoft® Excel spreadsheet to enter their evaluation of each ultrasound video clip. Images were scored against a 6-point Likert score, the CUSAS, which is shown in Figure 45. A CUSAS score of ≥ 3 is the minimum criterion for determining cardiac ventricular activity. External moderators also signed a Confidentiality Agreement, shown in Appendix R to maintain study integrity.

Figure 45

Cardiac Ultrasound Structural Assessment Score



Note. Cardiac Ultrasound Structural Assessment Scale reproduced from Backlund et al. (2010).

3.8 Statistical Methods

3.8.1 Study Size Calculation

A power analysis was based on 100% of participants achieving ≥ 80% knowledge quiz pass rate with a ±14.3 margin of error and 95% CI. The sample size in this study exceeds that of previously described simulation studies of nine to ten participants (Booth et al., 2015; Younger et al., 2016).

3.8.2 Statistical Analysis Plan

The primary statistical analysis was performed using SPSS®. The analysis plan shown Table 11 which includes descriptions of each dataset. Performance targets and binary logistic regression analyses used Statistical Analysis Software (SAS®) version 9.4 (www.sas.com). The confidence interval was set at 95%, and a significance level of 0.05 was applied. Confidence point estimates were calculated using the online tool from https://sample-size.net/confidence-interval-proportion/ and are available in the text. Missing data due to non-participant attendance were excluded and this is noted in frequency tables. For inter-rater reliability measures, missing scores were excluded pairwise (Pallant, 2020). The primary statistical analysis was the author's work with support from Dr. Nick Garrett. The binary logistic regression was the work of Dr. Nick Garrett with input from the author.

Table 11

Statistical Analysis Plan

Variable	Data Type	Test	Assumptions
Sample Size	Nominal	Power Analysis	≥ 80% pass mark in the knowledge quiz
Gender	Categorical entered as nominal	Chi-Square Goodness of Fit Test	1 Categorical variable 25 Observations
Hands-off-time (HOT)	Continuous ordinal	One sample Kolmogorov-Smirnov Test	Scale is ordinal samples are from the same set of values.
		Descriptive	Mean, median, mode, standard deviation, maximum and minimum times, CIs, IQR, Skewness and Kurtosis, Q-Q plot
	Binary	Binary Logistic Regression	Binary data
	< 10 seconds or > 10 seconds	'Unadjusted Person Effect'	Observations are independent
	Repeated measures < 10 seconds or > 10 seconds	GENMOND QIC Goodness of Fit	
		First-order autoregressive model (AR)	Dependence on the previous recording.
		GENMOND Procedure Type 3 Analysis	Uses sums instead of squares
		GENMOND Repeated Measures Logistic Regression 'Person Effect'	Does not depend on the order in which the terms for the model are specified

CUSAS Simulation and Echo stations	Binary > or ≥ 3	Cross tabulation	Relates to study design
	Ordinal	Cohen's Weighted Kappa Measure of Agreement	Ordinal
	Binary < 3 or > 3	Cohen's Weighted Kappa Measure of Agreement	Relates to study design
CAFE Exam	Binary Correct or incorrect	Cross tabulation	Relates to study design
Knowledge Quiz	Continuous ordinal	Shapiro-Wilks Test, Q-Q plot and histogram Wilcoxon Signed Rank Test	Repeated measures, matched subject design
Hands off time versus CUSAS Score (Simulations)	Continuous ordinal and Binary < 3 or ≥ 3	Cross tabulation	Relates to study design
Study Participant Simulation Echo Competency with Scan Number	Binary < 3 or > 3 ordinal	Cross tabulation	Relates to study design
Ultrasound Image Depth Simulations	Ordinal	Scatter Plot	
Reviewer A Simulation CUSAS with Image Depth Phases II and III	Ordinal	Spearman's Rho	Two ordinal variables, paired observation, normal distribution

3.8.3 Research Question One Methods

The HOT was measured when simulated chest compressions physically stopped, and compressions were restarted after the ultrasound was completed. Hands-off-time occurred three times per simulation for each station, with an ultrasound scan interpretation every 2-minutes between CPR cycles. Every participant simulation generated three ultrasound images and three HOT intervals, which were measured by the assessor using a manually operated stopwatch. Hands-off-time intervals were recorded in seconds (mm:ss) and handwritten on the simulation assessment form for each study participant. This analysis focused on the HOT data collected from assessment forms. The main objective was to examine the distribution of HOT measurements and compare the mean times between phases II and III. An evaluation of the normality of the data was presented using the Kolmogorov-Smirnov test. Additionally, the data was presented as dichotomous groupings based on HOT scores: HOT < 10 seconds or ≥ 10 seconds.

Binary logistic regression was used to examine the factors contributing to achieving the target of < 10 seconds HOT. As the data involved individuals who produced HOT for multiple simulations across two phases of experiments, there is an inherent 'person effect' due to individual variation. The two models analysed variability between the 'unadjusted for person effect' and 'person effect'. The person effect represents factors which were perceived to affect the variables. These perceived variables include study participant fatigue, knowledge consolidation, equipment and simulation familiarity and learned responses. The model assumed 0 = greater than or equal to 10 seconds and 1 = less than 10 seconds. The threshold for the pulse check pause variable of < 10 was 9.99 seconds.

3.8.4 Research Question Two Methods

The CUSAS image scoring system developed by Backlund et al. (2010) was used to grade echo images based on specific visual parameters, including effective imaging of the myocardium and ventricular chamber visibility. The CUSAS Likert scale ranges from numbers 1 to 6, with a score of ≥ 3 considered adequate for image interpretation of the fluid and function assessment (CAFE exam). External reviewers (A and B) evaluated ultrasound clips against the CUSAS scores shown in Figure 46. This analysis evaluates study participants' CUSAS scores from simulations stations and echo skills stations.

Figure 46

Cardiac Ultrasound Structural Assessment Score

1 =	No myocardium visualised
2 =	Myocardium visualised
3 =	Partial myocardium visualised
4 =	Multiple partial chambers visualised (including at least one ventricle)
5 =	Full ventricle visualised
6 =	Multiple full ventricles visualised (including at least one ventricle)

Note. Cardiac Ultrasound Structural Assessment Scale reproduced from Backlund et al. (2010).

For the evaluation of ultrasound images, external reviewers provided their interpretation of the CUSAS score, which was then entered into a Microsoft® Excel version 16.74 (2023) spreadsheet stored on Google® Drive. Missing data occurred when reviewers did not enter a value due to missing images or image quality issues. Additionally, in some

cases, reviewer A entered a CUSAS score, while reviewer B did not. Data points missing from either reviewer were excluded pairwise, reducing the impact of incomplete and missing interpretations. A cross-tabulation and inter-rater reliability analysis was also evaluated using Cohen's Weighted Kappa Measure of Agreement to assess the consistency of evaluations between raters.

Echo images were also evaluated against the same CUSAS scoring system used in the simulation image review. Each participant took three images, one of each echo view (SC4, PSLA and A4C) in phases II and III. External reviewers A and B evaluated images from both phase II and III echo skills stations. The analysis describes the CUSAS echo skills station characteristics as a binomial evaluation of images rated < 3 or ≥ 3. Secondly, an inter-rater reliability analysis was performed using Cohen's Weighted Kappa of Agreement.

3.8.5 Research Question Three Methods

The CAFE exam asked questions evaluating 'fluid' and 'function' of the heart during simulation stations. Data recorded by the participant was binary (yes or no) for answers pertaining to fluid: "Is there a pericardial effusion?", "Is there evidence of tamponade?". The function assessment evaluation of left ventricular squeeze determining weak, vigorous or none and valvular movement (yes or no). All interpretations were entered into SPSS® as a binary interpretation of a 'correct' or 'incorrect' answer. Analyses performed included frequency and descriptive data with a crosstabulation to show study participant ID with phase and interpretation.

The original mock scan image interpretations were determined by the author in conjunction with Dr Scott Bomann as the Director of Emergency Ultrasound at Wellington Emergency Department.

3.8.6 Research Question Four Methods

Test results were generated from the online Canvas knowledge quiz were entered into the SPSS® database following each group. Test scores were entered as a point score out of 12. An individual pass mark of ≥ 80% included a quiz score of 9.6 out of 12. Quiz question nine was awarded 0.16 points per partial answer with six correct answers awarded one full point. The analysis reviews the knowledge quiz characteristics evaluation of the differences between phase II and III and groups A and B. A Wilcoxon Signed Rank Test was used to compare two related samples testing the mean difference between phase II and III for statistical significance. A further examination of individual quiz questions evaluated gaps in knowledge to inform future education programs.

3.8.7 Incidental Findings Methods

A post hoc analysis was conducted to address questions arising from the research aims, providing additional context and support for future research and education in this field.

Hands off time versus CUSAS score. An analysis of phase, simulation station and hands-off-time versus CUSAS score was performed using a cross-tabulation.

Analysis of Competence. Skill competency was not part of the research questions but formed part of the OSAUS assessments. Participants performed three ultrasound scans per simulation at each 10 second pulse check pause. The simulation station assessor evaluated the competence of the participant in acquiring an ultrasound image for each scan acquisition. If the assessor did not deem the study participant competent, the participant was marked as 'Not Yet Competent' on the assessment form. This section will describe simulation competency characteristics between study participants.

Echo View Quality. While the quality of the echo view is not a primary research question, obtaining a clear echo view and relevant anatomical landmarks are crucial for the CAFE evaluation. The results from this section will inform education and future research in this area. Study participants used one of three echo views (SC4, A4C and PSLA) during the CAFE exam. The SC4 view was preferred and is the most sensitive for evaluating pericardial effusion. Due to the potential for CPR interruption, the parasternal view was the least preferred of the two alternatives for pre-imaging. Study participants were encouraged to begin the CAFE exam with the SC4 view. If, after two attempts, they could not achieve this view, the participant was taught to explore an alternative view with the preferred option of apical before parasternal due to access difficulties during CPR.

Echo Skills Competency. Each participant was assessed for competency to achieve the correct echo view, probe orientation, optimise the image, and identify sonographic structures within each view. Data is presented using a crosstabulation showing echo skills assessment competence by phase.

Ultrasound Image Depth Selection. Study participants were taught to pre-set their ultrasound image to a depth of 23 cm. This depth is considered adequate to capture an image of the heart in most patient SC4 view. The participant could adjust their image depth as required for each scan. Data is presented using a scatter plot, bar graph and Spearman's Rho to determine the strength of association between image depth selection and CUSAS score.

3.8.8 Method Limitations

Hands-off-Time. The timing of hands-off intervals was recorded by assessors using a stopwatch, introducing potential biases due to assessor limitations and different assessors across phases.

Study Protocol Deviation. During phase II for group A, a technical glitch with the knowledge quiz inadvertently exposed a participants' identity. The participant attempted to complete the knowledge quiz at the time, but the quiz would not advance to the next question. The knowledge quiz supervisor (AS) could not resolve the situation without the author's participation. Unfortunately, this revealed the participants' study ID. The technical issue was resolved quickly with a second quiz being started from the stopped point, and both quiz marks were combined to form their overall quiz score. For transparency, the participant and supervisor (BT) were advised immediately.

Wellington Simulation Suite. Accessing the AUT login page and knowledge quiz required an internet connection. The Wellington Regional Hospital guest network could not load ultrasound videos and images within the quiz. The individual laptops were, therefore, tethered to personal cell phones used as hotspots. However, internet speed remained an issue. In phase III group B, all laptops were tethered to WFA Vodafone® 3G portable modems, which improved internet speed issues.

Simulation Verses the Real-world Setting. The limitations of simulation in cardiac arrest include fidelity in replicating adequate cognitive loading and clinical variety. However, simulation is demonstrated in the literature as a useful tool in ultrasound transferable to the clinical setting (Bowman et al., 2021). The less transferrable skills include those that are difficult to simulate, such as healthy volunteer clinical variation and high cognitive loading.

Assessor Variation. The increased burden on the hospital system and healthcare providers due to SARS-CoV-2 made recruiting and retaining qualified ultrasound faculty challenging, leading to short-notice changes that affected continuity across groups. Consequently, assessor inter-rater reliability was not analysed due to limited faculty and time, a recognised limitation of this study.

Salvation Army Church. A portable modem provided by WFA was used to enhance internet connectivity for efficient video content loading during the phase II quiz. Though it performed flawlessly during a pre-test, on May 27th, 2022, a couple of unforeseen technical issues emerged. At 1400 hours, an unexpected Canvas outage led to a delay in initiating the quiz by 40 minutes (S. Schutte, personal communication, June 2, 2022). Additionally, the modem unexpectedly could not support the data demands of the quiz for multiple participants, hampering the smooth flow of the quiz, especially when loading data-intensive ultrasound images. The author sent an email on May 29th, 2022, thanking the participants, providing information about the technical issue, and asking if they had any feedback. Email responses were sent to Dr. Bronwyn Tunnage, who anonymised responses. Two responses were received, one from the invigilator who indicated that study participant 23 could not answer question 12 as it would not load. The invigilator loaded question 12 onto their phone at the time, and the participant said which answer they believed was correct. Participant 12 answered the question correctly and was scored accordingly. The second respondent, study participant 21, replied:

> I lost about one and a half minutes at the start due to the arrow up down keys not working. I have not used the touch pad type of laptop that we sat the quiz on…am used to using a mouse, and I think the unfamiliarity with the touch pad also slowed down my progress. The issue with the arrow keys was sorted by tapping on them repeatedly, but unfortunately this had eaten into my 15-minute time frame. I could not make the videos run either, so just had to guess the structures from the still frames.

Chapter 4 Results

This chapter analyses the key findings from the research data collected. The results are presented using the INSPIRE Guidelines. The INSPIRE group modified STROBE with an extension for the Simulation-Based Research (SBR) (Cheng et al., 2016). The following sections examine the study participant characteristics, missing data, simulation HOT, CUSAS scores, the CAFE fluid and function assessment, skill competence, echo skills station CUSAS scores, the knowledge quiz, and other analyses supporting the research aims.

4.1.1 Analysis of Simulation Data

The following sections will present the data analysis for each simulation research questions. The simulation assessments aim to answer research questions one, two and three:

1. Can 100% of paramedics who receive cardiac arrest-focused echo (CAFE) education and training acquire ultrasound images within the 10 second pulse check pause at simulated cardiac arrests at least 90% of the time? This question examines the hands-off-time Research Question One: Hands off Time Results.
2. Can 100% of CAFE trained paramedics achieve a Cardiac Ultrasound Structural Assessment Scale (CUSAS) score of ≥ 3 in at least 90% of simulated cardiac arrest echo attempts? This question evaluates all paramedic acquired ultrasound images from echo and simulation assessments against the Likert scale Research Question Two: Quality of Imaging.
3. Can 100% of CAFE trained paramedics accurately identify the presence or absence of pericardial effusion, pseudo-PEA, true PEA, left ventricular contraction and valvular movement as measured by the CAFE exam fluid and function assessment analysis in ≥

90% of cases? This question evaluates the assessment of the CAFE exam Research Question Three: Interpretation.

4.2 Research Question One: Hands off Time Results

Overall, there were 243 HOT measurements recorded. In phase II 29 participants recorded three HOT measurements each (n = 87). In phase III 26 participants recorded six measurements each (n = 157). One participant did not attend phase II and was withdrawn from phase III. Three participants did not attend phase III. A frequency table of study participant attendance is shown in Figure 47.

Figure 47

Study Participant Phase Attendance with Number of HOT Occurrences

		Phase number		Total HOT Occurrences
		Phase II	Phase III	
Study participant ID	1	3	6	9
	2	3	6	9
	3	3	6	9
	4	3	-	3
	5	3	6	9
	6	3	-	3
	7	3	6	9
	8	3	6	9
	9	3	-	3
	10	3	6	9
	11	3	6	9
	12	3	6	9
	13	3	6	9
	14	3	6	9
	15	3	6	9
	16	3	6	9
	17	3	6	9
	18	3	6	9
	19	3	6	9
	20	3	6	9
	21	3	6	9
	22	3	6	9
	23	3	6	9
	24	3	6	9
	25	3	6	9
	26	3	6	9
	27	3	6	9
	28	3	6	9
	29	3	6	9
	30	-	-	-
Total		87	156	243

Note. Participants four, six and nine did not attend phase III. Participant 30 did not attend phase II and therefore was withdrawn from phase III also.

In phase II, there were 87 HOT measurements with a mean time of 10.9 seconds (*SD* = 3.7, 95% CI [10.1, 11.7]). In phase III, there were 156 HOT measurements with a mean of 8.9 seconds (*SD* = 1.9, 95% CI [8.6, 9.2]). The inclusion of a second simulation assessment provided more opportunities to gather HOT data, leading to a larger and more comprehensive dataset for analysis in phase III. In the combined analysis of HOT data from phase II and III, the average HOT was 9.6 seconds (*SD* = 2.8, 95% CI [9.3, 10.0]) displayed in Table 12. Additionally, a scatter plot (Figure 48) visually represents the HOT scores of each study participant. Participants' one to fifteen (group A) showed a learned effect with improvement between phase II and III. However, participants' sixteen to twenty-nine showed almost no learned effect but better performance across both phases.

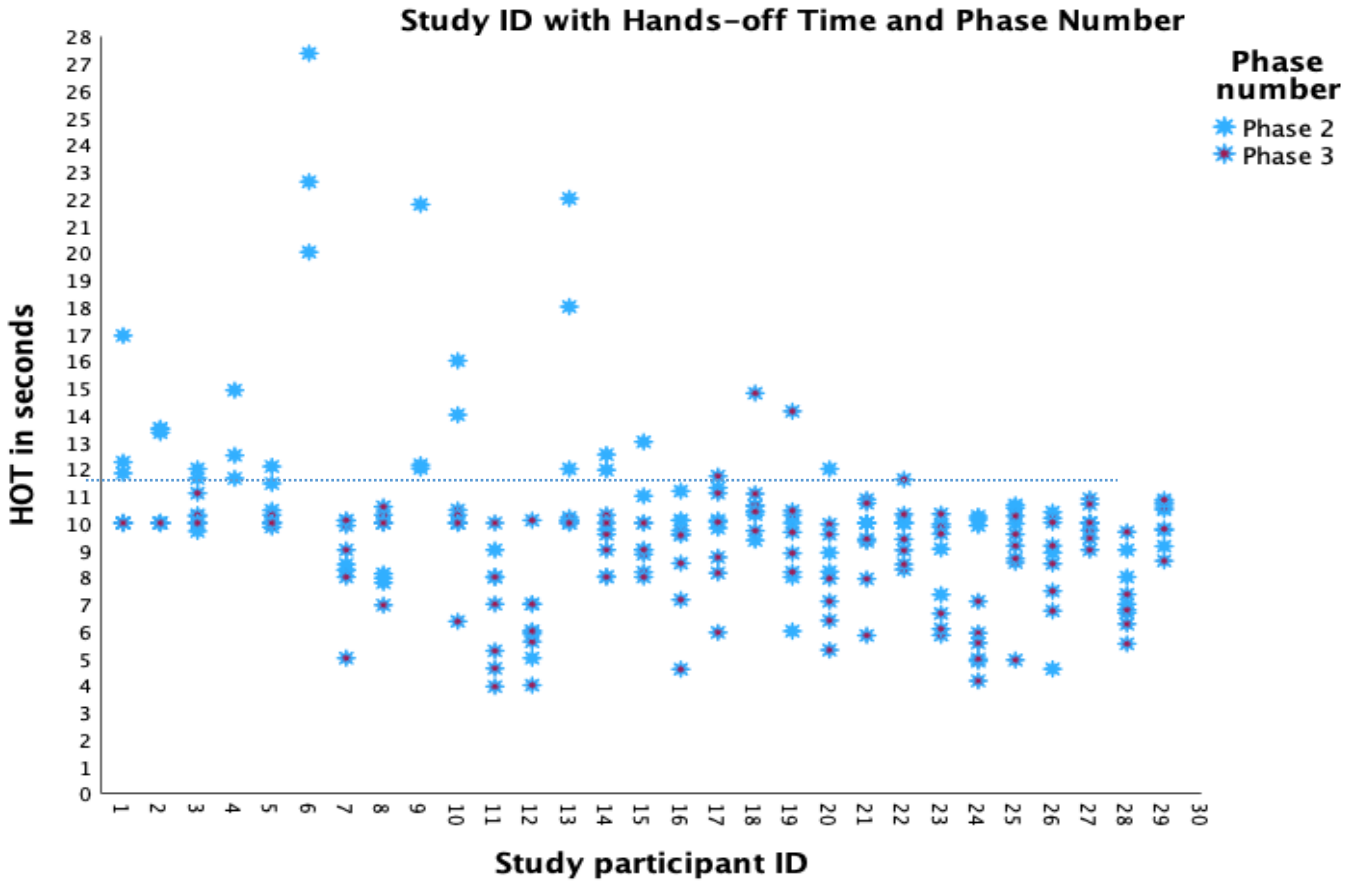
Table 12

Hands-off-time Descriptive Analysis of Phases II, III and Combined

Valid				Statistic	Std. Error
HOT in seconds	*n*	87			
	Phase II	Mean		10.9	0.25
		95% CI of Mean	Lower Bound	10.1	
			Upper Bound	11.7	
		Median		10.1	
		Mode		10.0	
		Std. Deviation		3.7	
		Minimum		4.6	
		Maximum		27.3	
		Interquartile Range		3.0	
		Skewness		1.98	0.258
		Kurtosis		5.38	0.511
	n	156			
	Phase III	Mean		8.9	0.15
		95% CI of Mean	Lower Bound	8.6	
			Upper Bound	9.2	
		Median		9.7	
		Mode		10.0	
		Std. Deviation		1.9	
		Minimum		3.9	
		Maximum		14.8	
		Interquartile Range		2.0	
		Skewness		-0.672	0.194
		Kurtosis		0.463	0.386
	n	243			
	Combined	Mean		9.6	0.18
		95% CI of Mean	Lower Bound	9.3	
			Upper Bound	10.0	
		Median		10.0	
		Mode		10.0	
		Std. Deviation		2.8	
		Minimum		3.9	
		Maximum		27.3	
		Interquartile Range		2.2	
		Skewness		2.01	0.156
		Kurtosis		9.39	0.311

Figure 48

Scatter Plot of Study Identification Number with Hands-off Time and Phase Number



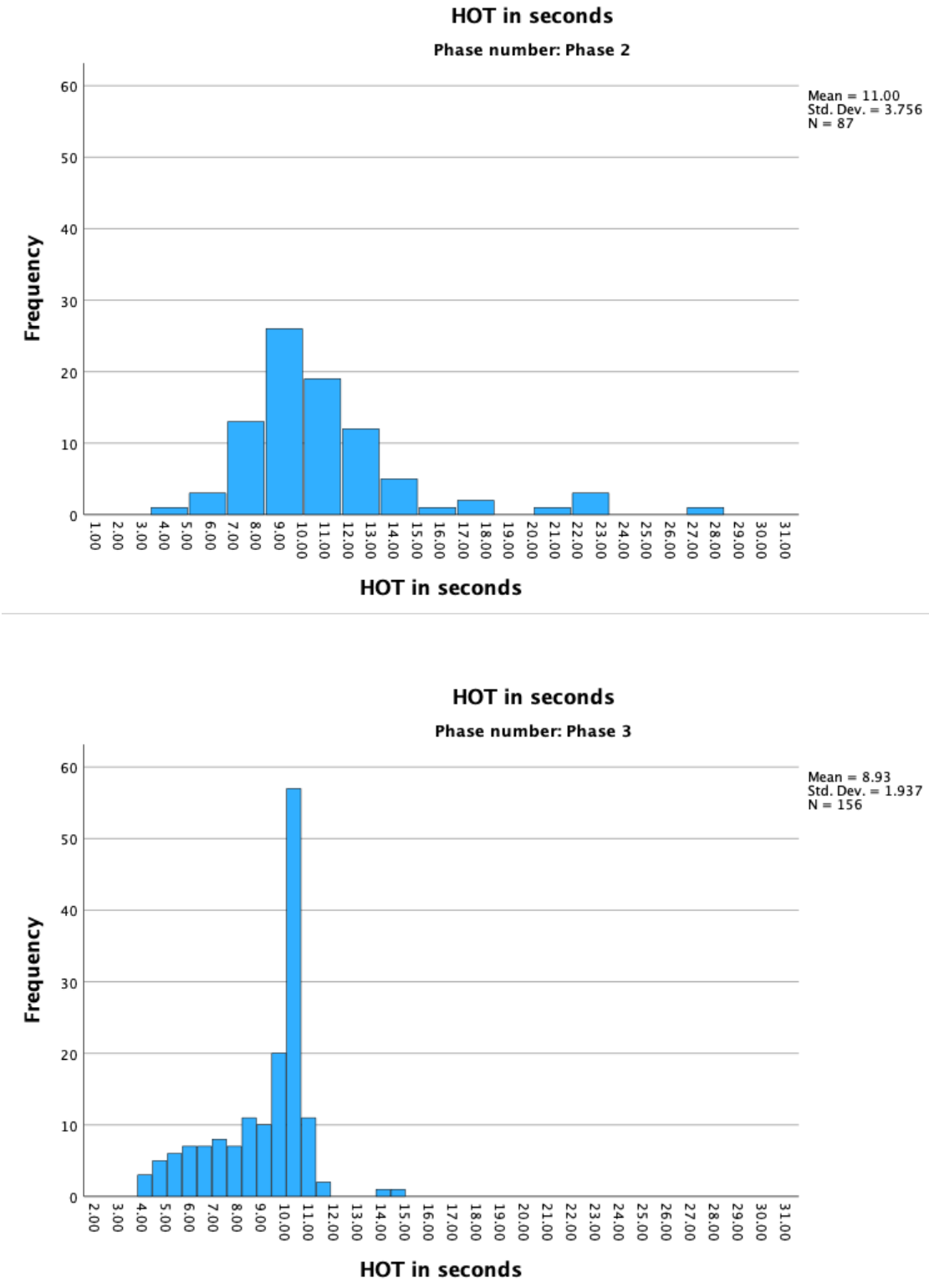
Note. HOT = Hands-off-time, ID = Identification.

4.2.1 Data Distribution

The descriptive data shows that the distribution of HOT values was skewed. Phase II showed a positive skew (1.98), with more HOT towards the right. Phase III showed a negative skew (-0.672) with greater HOT to the left. The kurtosis values (5.83) indicate that the distribution in phase II had more extreme values (heavier tails); however, phase III tends to be flatter (0.463, lighter tails) with fewer extreme values. Figure 49 shows the HOT in seconds by phase, represented in a histogram.

Figure 49

Hands-off-time Histogram Phase II and III



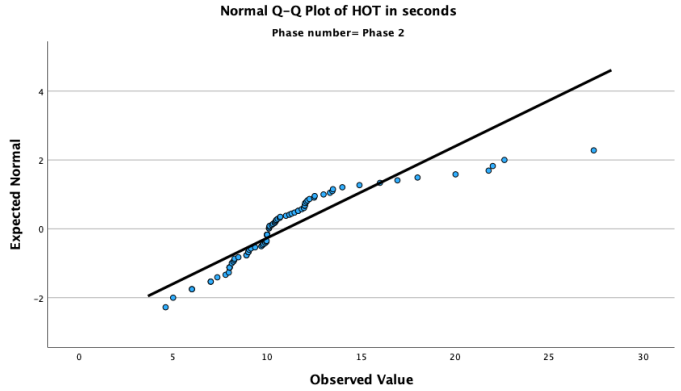
Note. HOT = Hands-off-time.

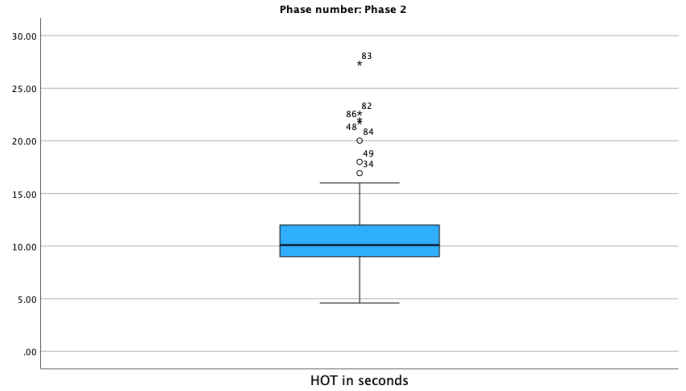
A one-sample Kolmogorov-Smirnov ($D(243) = 0.185$, $p = < 0.001$) was used to determine if the data comes from a normal distribution. A *p*-value less than 0.05 supports evidence that the distribution significantly differs from the normal, which is the case for this dataset (Pallant, 2020).

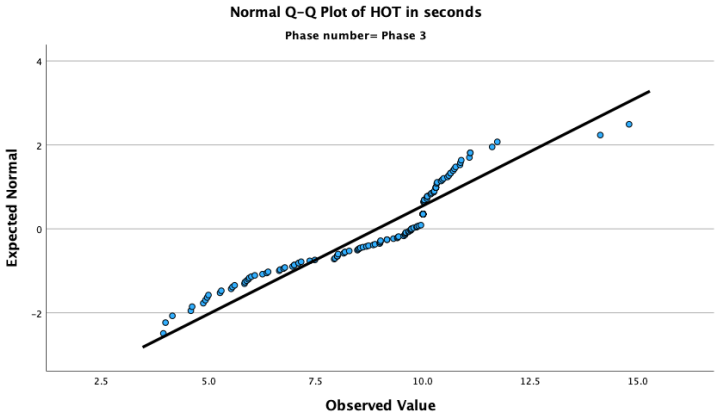
A Quantile-Quantile (Q-Q) plot was used to present phases II and III graphically, representing the theoretical distribution of data assuming a normal distribution. Based on the observed distribution shown in Figure 50, phases II and III do not meet the assumption for normality, and therefore, non-parametric statistical tests are appropriate for the analysis of HOT. Extreme outliers are also shown in box and whisker graph in Figure 50 and are included in all statistical analyses as these measures are part of the key objective when analysing ultrasound integration into the 10 second pulse check pause.

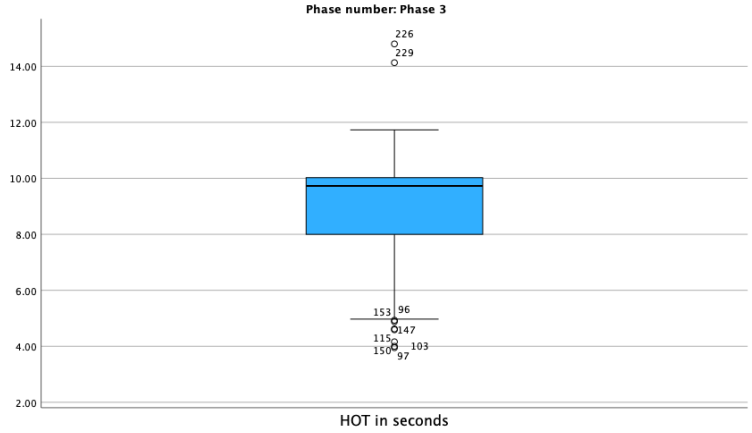
Figure 50

Hands-off Time Q-Q Plot and Box and Whisker Graph





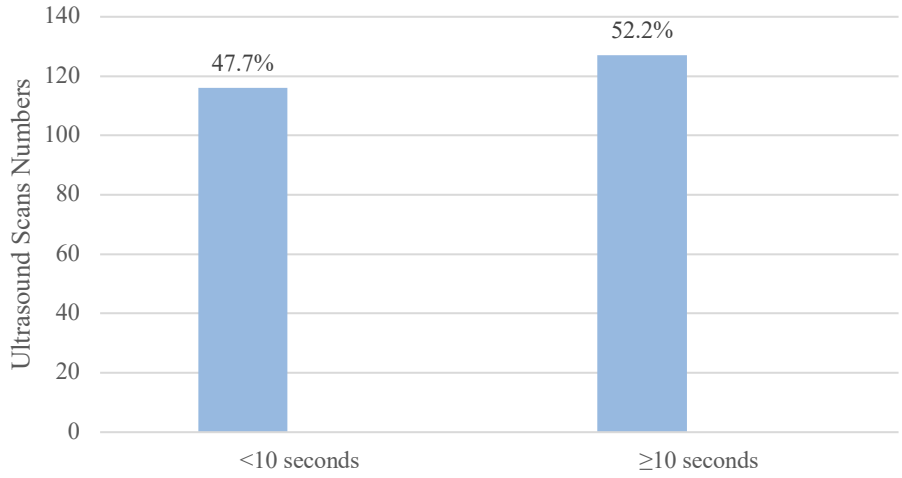




An analysis of the combined data showed 116 of 243 of scan attempts (47.7%, 95% CI [41.3, 54.2]) were achieved in < 10 seconds, with 127 (52.2%, 95% CI [45.7, 58.6]) of participants with a scan time ≥ 10 seconds shown in Figure 51.

Figure 51

Hands-off-time Combined < 10 or ≥ 10 Seconds



Note. < 10 = 9.99 seconds, ≥10 = 10.00 seconds.

A cross-tabulation shown in Figure 52 examines phase and dichotomous HOT differences between phases II and III. In phase II a HOT of < 10 seconds was achieved in 32 (36.7%, 95% CI [26.6, 47.8]) attempts, and 84 (53.8%, 95% CI [45.6, 61.8]) in phase III. There were 55 (63.2%, 95% CI [52.2, 73.3]) occurrences achieving ≥ 10 seconds in phase II and 72 (46.1%, 95% CI [38.1, 54.3]) in phase III.

Figure 52

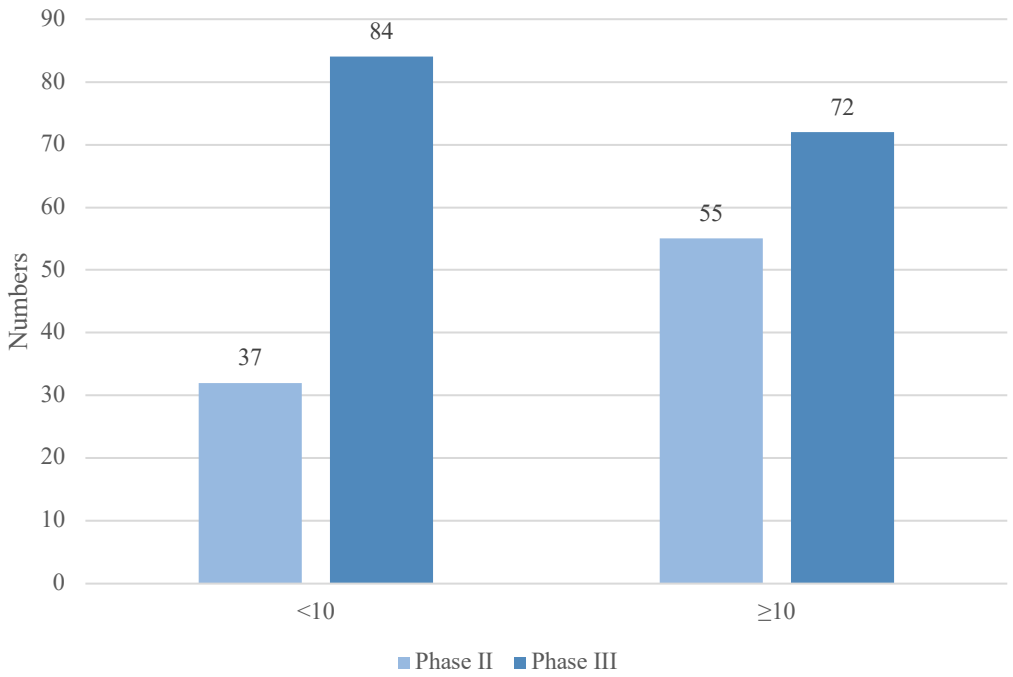
Cross-tabulation of Hands-off-time with Phase

	Hands off time		Total
	< 10 seconds	≥ 10 seconds	
Phase 2	32	55	87
Phase 3	84	72	156
Total	116	127	243

Figure 53 displays the phase and HOT data as a histography showing a 17% improvement in achieving a < 10 seconds between phases II and III.

Figure 53

Hands-off-time Phase II and III Comparison



When examining HOT that fall marginally outside of the 10.00 seconds from 10.01 to 10.99 seconds there are 47 (19.3%, 95% CI [14.5, 24.8]) of 243 scans that meet this criterion as shown in Table 13.

Table 13

Hands-off Time 10.01 to 10.99 seconds

Valid		Statistic
n		47
Mean		10.3
Median		10.3
Mode		10.1
Std. Deviation		0.25
Range		0.88
Minimum		10.0
Maximum		10.8
Percentiles	25	10.1
	50	10.3
	75	10.5

However, dividing the data into < or ≥ 10 seconds without considering the individual participant effect suggests that 48% of the attempts were achieved in less than 10 seconds. This discrepancy suggests that other factors besides scan acquisition contribute to the results and requires further analysis which is explored in the next section.

4.2.2 Binary Logistic Regression

The analysis compared phase number and simulation station, categorizing HOT as either ≥ 10 seconds or < 10 seconds. The first model examined HOT against phase and station without adjusting for individual differences. The second model included participant

identification (person effect). Table 14 illustrates that in Phase II, the percentage of achieving < 10 seconds HOT was 59%, 37%, and 37% for phase and stations 2-1, 2-2, and 2-3 respectively, compared to Phase III which showed 59% and 49% for stations 3-1 and 3-2. This variation suggests that certain phases or stations were more challenging for some healthy model volunteers or simulation conditions.

Table 14

Hands-off-time by Phase and Station

	Phase number and simulation station number										
Hands-off-time	2-1	%	2-2	%	2-3	%	3-1	%	3-2	%	Total
≥ 10 seconds	11	41	19	63	25	83	32	41	40	51	127
< 10 seconds	16	59	11	37	5	37	46	59	38	49	116
Total	27	100	30	100	30	100	78	100	78	100	243

4.2.3 Model Unadjusted for Person Effect

An odds ratio GEE analysis measured the strength of association between phase, station, and HOT as shown in Table 15. Phase II and simulation station one was used as the baseline reference station. The results showed a significant difference between the reference station (2-1) and phase II simulation station three (2-3), (OR = 7.1, 95% CI [2.12, 25]). However, phase II simulation station two (OR = 2.50, 95% CI [0.86, 7.14]), phase III simulations station one (OR = 1.01, 95% CI [0.41, 2.5]) and phase III simulations station two (OR = 1.50, 95% CI [0.66, 3.10] effect combinations were not significantly different to the reference station.

Table 15

Unadjusted Odds Ratios

		95% CI	
Effect	Odds Ratio	Lower	Upper
phase/station 2-2 vs 2-1	2.50	0.86	7.14
phase/station 2-3 vs 2-1	7.14	2.12	25
phase/station 3-1 vs 2-1	1.01	0.41	2.5
phase/station 3-2 vs 2-1	1.50	0.66	3.10

Note. Measurements rounded. SAS®system analysis.

Therefore, the results suggest that participants exposed to phase II and simulation station three had significantly higher odds of taking ≥ 10 seconds to acquire a scan than those exposed to the reference station. However, the odds ratio for the remaining phase and station effect combinations were not significantly different from the reference station.

4.2.4 Model Adjusted for Person Effect – Repeated Measures

The GENMOD procedure used the quasi-likelihood information criterion generalised linear model to analyse repeated measures of HOT in the study. The analysis included 29 study participants, and a total of 243 observations were included in the analysis. The QICu value of 326.8 is a measure of goodness of fit for this model. To model the repeated measures of HOT, it would be necessary to specify a structure for the study participant correlation across measures. A first-order statistical autoregressive model AR (1) was used, which assumes that the HOT score for each station was only dependent on the performance in the previous station and not any other station performances. A type three analysis was used to measure likelihood ratios instead of sums of squares.

Overall, the *p*-value for differences across all phases and simulation stations is $\chi^2(4, N = 243) = 9.01$, $p = 0.060$ which is not statistically significant ($p = > 0.05$) suggests that the individual tended to perform similarly across all phases and simulation stations. However, in practical terms, this means that while there may be some indication of differences in performance across phases and simulation stations, these differences are not convincingly significant based on the chosen threshold.

An analysis of the odds ratio shown in Table 16 measured the association between phase-station and HOT, adjusting for the 'person effect'. Phase II, simulation station one, remained the reference variable. The results showed a significant difference between the reference group (2-1) and the phase II simulation station three (OR = 7.69, 95% CI [1.35, 9.09]).

Table 16

Adjusted Odds Ratio

	Odds Ratio	95% Confidence Limits	
Label		Lower	Upper
Exp (phase/station 2-2 vs 1-1)	2.70	0.83	9.09
Exp (phase/station 2-3 vs 2-1)	7.69	1.35	9.09
Exp (phase/station 3-1 vs 2-1)	1.06	0.43	2.63
Exp (phase/station 3-2 vs 2-1)	1.40	0.55	3.57

Overall, the type three Generalised Estimating Equation (GEE) analysis ($p = 0.060$) suggests that individuals tend to perform similarly across all variables with or without the

person effect. The output of a binary logistic regression model with the addition of variables showed that the simulation station had an impact on both ‘unadjusted’ and ‘person effect’. The odds ratio of simulation station three unadjusted was 7.14 (95% CI [2.12, 25]), and the addition of the ‘person effect’ showed a further increase in the odds ratio of 7.69 (95% CI [1.35, 9.09]).

4.3 Research Question Two: Quality of Imaging

Out of 243 simulation stations from phases II and III, 234 CUSAS images were reviewed and scored by reviewers A and B. Nine images were excluded pairwise. A cross-tabulation of study participant IDs all phase simulation evaluations and Rater A CUSAS scores of $<$ or ≥ 3 is shown in Table 17.

Table 17

Cross-tabulation of Study Participant, Simulation CUSAS < 3 or ≥ 3 by Rater A

		Rater A (Binned)			Total
		No image to review	< 3	≥ 3	
Study participant ID	1	-	3	6	9
	2	-	4	5	9
	3	3	4	2	9
	4	-	3	-	3
	5	-	3	6	9
	6	2	-	1	3
	7	2	3	4	9
	8	-	-	9	9
	9	-	2	1	3
	10	-	1	8	9
	11	-	1	8	9
	12	-	1	8	9
	13	-	-	9	9
	14	-	6	3	9
	15	-	1	8	9
	16	-	-	9	9
	17	-	-	9	9
	18	-	1	8	9
	19	-	-	9	9
	20	-	1	8	9
	21	-	1	8	9
	22	-	-	9	9
	23	-	-	9	9
	24	-	-	9	9
	25	-	-	9	9
	26	-	2	7	9
	27	-	2	7	9
	28	-	-	9	9
	29	-	1	8	9
Total		7	40	196	243

4.3.1 Descriptive Data

Reviewer A and B assessed 87 participant images (five images excluded pairwise) in phase II and 152 in phase III (four images excluded pairwise). A descriptive analysis of phase II CUSAS scores for both reviewers is shown in Table 18. The data showed a mean CUSAS of ≥ 3 for reviewer A (M = 3.8, SD = 1.3) and reviewer B (M = 3.5, SD = 1.3). In phase III, the mean scores for both reviewer A (M = 4.2, SD = 1.5) and reviewer B were also ≥ 3 (M = 3.6, SD = 1.4).

Table 18

CUSAS Simulation Station Descriptive Statistics Reviewer A and B

Phase number			Reviewer A Sim *n*	Reviewer B Sim *n*
Phase II	*n*	Valid	82	82
		Missing	5	5
	Mean		3.8	3.5
	Median		4.0	4.0
	Std. Deviation		1.3	1.3
	Range		6.0	6.0
	Minimum		1	1
	Maximum		6.0	6.0
Phase III	N	Valid	152	152
		Missing	4	4
	Mean		4.2	3.6
	Median		4.0	4.0
	Std. Deviation		1.5	1.4
	Range		5.0	5.0
	Minimum		1	1
	Maximum		6.0	6.0

Note. Sim = Simulation

A detailed cross-tabulation analysis of simulation CUSAS scoring (1-6) by reviewer A and B from phases II and III, is shown in Table 19. Reviewers agreed the most (34 images, 14.5%, 95% CI [10.2, 19.7]) when multiple chambers were visualised with a CUSAS of four. Additionally, the second most agreeable CUSAS score was one with agreement on 22 images.

Table 19

Cross-tabulation Simulation CUSAS Score Between Reviewers A and B

	Reviewer A						
Reviewer B	No myocardium visualised (1)	Myocardium visualised (2)	Partial myocardium visualised (3)	Multiple partial chambers visualised (including at least one ventricle) (4)	Full ventricle visualised (5)	Multiple full chambers visualised (including at least one ventricle) (6)	Total
No myocardium visualised (1)	22	2	1	1	-	-	26
Myocardium visualised (2)	2	3	3	17	1	-	26
Partial myocardium visualised (3)	2	5	-	34	3	1	45
Multiple partial chambers visualised (including at least one ventricle) (4)	-	1	4	34	5	18	62
Full ventricle visualised (5)	-	-	-	26	5	31	62
Multiple full chambers visualised (including at least one ventricle) (6)	-	1	-	2	1	9	13
Total	26	12	8	114	15	59	234

Note. CUSAS = Cardiac Ultrasound Structural Assessment Scale, 0 = No image obtained to grade, 1 = No myocardium visualised, 2 = Myocardium visualised, 3 = Partial myocardium visualised, 4 = Multiple partial chambers visualised (including at least one ventricle), 5 = Full ventricle visualised, 6 = multiple full chambers visualised (including at least one ventricle).

A cross-tabulation analysis of the combined phase II and III simulation CUSAS scores showed the number of images rated < 3 or ≥ 3 (Table 20). The combined phases showed a ≥ 3 CUSAS score for 83.7% (95% CI [78.4, 88.2]) of images for reviewer A (196) and 77.7% (95% CI [71.9, 82.9]) for reviewer B (182). Both reviewers agreed on a CUSAS of ≥ 3 for 173 (73.9%, 95% CI [67.8, 79.4]) cases. Despite the CUSAS scores showing small variability between reviewers, the images reviewed did not met the desired standard of ≥ 3 in 90% of cases.

Table 20

Cross-tabulation of CUSAS Simulation < 3 or ≥ 3 scores by Reviewer A and B

		Reviewer B CUSAS Simulation		
		< 3	≥ 3	Reviewer A Total
Reviewer A CUSAS Simulation	< 3	29	9	38
	≥ 3	23	173	196
Reviewer B Total		52	182	234

4.3.2 Cohen's Weighted Kappa for Reviewer Simulation CUSAS Analysis

A weighted Kappa considers the Likert scale data of CUSAS scoring. Values are weight-based on distance from concordance, reflecting importance considering the magnitude of disagreement. A cross-tabulation analysis shows the highest level of agreement for reviewers A and B was the CUSAS of 4, with 34 (54.8%) images agreed by both reviewers and no myocardium visible (n = 22).

The weighted Kappa statistic showed the reliability of external reviewers A and B agreeing on CUSAS images scoring was 0.453 (95% CI [0.37, 0.527], p = < 0.001) shown in

Table 21. This shows a moderate agreement between reviewers that is beyond what would be expected by chance alone (Barton & Peat, 2014).

Table 21

Cohen's Weighted Kappa Simulation

			Asymptotic		95% CI	
Ratings	Weighted Kappa[a]	Std. Error[b]	z[c]	Sig.	Lower Bound	Upper Bound
Reviewer A Reviewer B	0.453	0.038	11.994	< 0.001	0.379	0.527

a. The estimation of the weighted Kappa uses linear weights.

b. Value does not depend on either null or alternative hypotheses.

c. Estimates the asymptotic standard error assuming the null hypothesis that weighted kappa is zero.

4.3.3 Echo Skills CUSAS

Of the 160 echo skills stations images, reviewers A and B evaluated 85 images in phase II and 75 in phase III. Two images that were not acquired by the participant are listed as missing. A preliminary descriptive analysis of CUSAS scoring of combined phase II and III echo CUSAS scores shows a mean CUSAS score of ≥ 3 for reviewer A (M = 3.9, SD = 1.4) and B (M = 3.4, SD = 1.3) as shown in Table 22.

Table 22

Echo Skills CUSAS Score Combined Phases II and III

Reviewer		A	B
		ECUSAS Combined	ECUSAS Combined
n	Valid	160	160
	Missing	2	2
Mean		3.9	3.4
Median		4.0	4.0
Std. Deviation		1.4	1.3
Range		5	5
Minimum		1	1
Maximum		6	6

Note. A = reviewer A, B = reviewer B, ECUSAS = Echo Cardiac Ultrasound Structural Assessment Score

Similarly with the echo CUSAS scores categorised into dichotomous data of < 3 and ≥ 3, Table 23 shows reviewer A scored 123 (76.8%, 95% CI [69.5, 83.1]) images ≥ 3 while reviewer B 137 (85.6%, 95% CI [79.2, 90.6]). Both reviewers agreed on a score of ≥ 3 for 121 images (75.6%, 95% CI [68.2, 82.0]). Despite the CUSAS scores showing small variability between reviewers, most images met the desired standard of ≥ 3 in 90% of cases and did not meet the research aim.

Table 23

Cross-tabulation of Echo CUSAS < 3 or ≥ 3 scores from Reviewer A and B

		Reviewer B Echo CUSAS		
		< 3	≥ 3	Reviewer A Total
Reviewer A Echo CUSAS	< 3	21	16	37
	≥ 3	2	121	123
Reviewer B Total		23	137	160

4.3.4 Cohen's Weighted Kappa Reviewer Echo Skills CUSAS Analysis

A cross-tabulation analysis of 160 reviewer A and B echo skills CUSAS scores was carried out from phase II and III, including missing images re-coded as zero. A cross-tabulation analysis shows the highest level of agreement for reviewers A and B was the CUSAS of 4, with 32 (20.0%, 95% CI [14.1, 27.0]) images agreed by both reviewers, followed by 'no myocardium was visible' (n = 14) shown in Table 24. These results emulate the simulation's similar agreement CUSAS values of four and one.

Table 24

Cross-tabulation of CUSAS Echo Skills Station by Reviewer

		Reviewer A						
		No myocardium visualised	Myocardium visualised	Partial myocardium visualised	Multiple partial chambers visualised (including at least one ventricle)	Full ventricle visualised	Multiple full chambers visualised (including at least one ventricle)	Total
Reviewer B	No myocardium visualised	14	2	-	-	-	-	16
	Myocardium visualised	2	3	8	7	-	1	21
	Partial myocardium visualised	-	2	3	29	-	2	36
	Multiple partial chambers visualised (including at least one ventricle)	-	-	1	32	1	13	47
	Full ventricle visualised	-	-	3	12	9	11	35
	Multiple full chambers visualised (including at least one ventricle)	-	-	-	-	1	4	5
Total		16	7	15	80	11	31	160

Note. CUSAS = Cardiac Ultrasound Structural Assessment Scale, 0 = No image obtained to grade, 1 = No myocardium visualised, 2 = Myocardium visualised, 3 = Partial myocardium visualised, 4 = Multiple partial chambers visualised (including at least one ventricle), 5 = Full ventricle visualised, 6 = multiple full chambers visualised (including at least one ventricle)

A weighted Kappa statistic showed the reliability of reviewers A and B agreeing on CUSAS images scoring was 0.499 (95% CI [0.34, 0.58], $p = < 0.001$) shown in Table 25 corresponding with a moderate agreement (Barton & Peat, 2014). This indicates a moderate level of agreement between reviewers and a similar level of agreement to simulation images.

Table 25

Cohen's Weighted Kappa Echo Skills

		Asymptotic			95% CI	
Ratings	Weighted Kappa[a]	Std. Error[b]	z[c]	Sig.	Lower Bound	Upper Bound
Reviewer A Reviewer B	0.499	0.046	11.195	< .001	0.3409	0.589

a. The estimation of the weighted Kappa uses linear weights.

b. Value does not depend on either null or alternative hypotheses.

c. Estimates the asymptotic standard error assuming the null hypothesis that weighted kappa is zero.

In summary, overall, combining (n = 307 of 394) simulation (n = 196 of 234) and echo (n = 121 of 160) stations scores that achieved a ≥ 3 CUSAS showed 77.9% (95% CI [73.4, 81.9]) of scans met the not meeting the study aim of 90%.

4.4 Research Question Three: Interpretation

The research question aimed to assess study participants ability to identify the presence or absence of pericardial effusion, pseudo-PEA, true PEA, left ventricular contraction, and valvular movement using the CAFE exam fluid and function assessment and the 12-question knowledge Quiz. The data is presented in three tables. The first (Table 26) presents the CAFE exam simulation station question with pathological scan interpretation frequencies by phase number. The second (Table 27) CAFE exam interpretation by question

type, scan and phase number and the third (Table 28) presents the interpretation by view and scan number.

4.4.1 Pathological Scan Interpretation Study Participant

The data shown in Table 26 describes the breakdown of CAFE exam interpretations by question type and phase, aiming to highlight overall correct and incorrect interpretation for each phase. Specifically, in phase II, there were 348 completed interpretations and 624 in phase III. The total correct interpretation by phase is 320 (91.9%, 95% CI [88.5, 94.5]) in phase II and 557 (89.2%, 95% CI [86.5, 91.5]) in phase III. Overall, there was 877 (90.2%,95% CI [88.1, 92.0]) correct CAFE interpretations.

Table 26

Cross-tabulation of CAFE Exam Simulation Station Question with Pathological Scan Interpretation Frequencies by Phase Number

		CAFE Exam Interpretation						
Phase number		Is there a pericardial effusion? *	Is there a tamponade? **	Evaluate LV squeeze	Are the valves opening?	Combined Total	%	95% CI
Phase II	Correct	83	85	65	87	320	91.9%	88.5, 94.5
	Incorrect	4	2	22	-	28	8%	
	Total	87	87	87	87	348	100%	
Phase III	Correct	140	148	114	155	557	89.2%	86.5, 91.5
	Incorrect	16	8	42	1	67	11%	
	Total	156	156	156	156	624	100%	

Note. CAFE = Cardiac Arrest-Focused Echo

*The simulation scan series did not show pericardial effusion pathology, rather pseudo-PEA to true PEA progression of cardiac arrest.

**There was no tamponade pathology presented in the simulation scan series.

4.4.2 Pericardial Effusion

In phase II, out of the 87 interpretations, 83 (95%, 95% CI [91.0, 99.7]) were correct, indicating no pericardial effusion, while four interpretations were incorrect. In phase III, out of the 156 interpretations, 140 (90%, 95% CI [84.9, 94.4]) were correct, and 16 were incorrect. This showed a slightly lower accuracy rate compared to phase II, with a higher number of incorrect interpretations. Furthermore, when the data was separated by question, scan number and phase (Table 27) the analysis revealed that as the scan series progressed in difficulty, there was an increasing number of incorrect answers. In phase II from scan 1-3 there were two incorrect answers (scans 2-3) however in phase III there were nine and seven answers incorrect (scans 2-3). Overall, for both phases the total of correct interpretations (no pericardial effusion) was 223 of 243 scans 91.7% (95% CI [87.5, 94.9]).

Table 27

CAFE Exam Interpretation by Question Type, Scan and Phase Number

Is there a pericardial effusion?

Scan number			Correct	Incorrect	Total	%	95% CI
Scan 1	Phase number	Phase II	29	-	29	100	
		Phase III	52	-	52	100	
	Total		81	-	81	100	
Scan 2	Phase number	Phase II	27	2	29	93.1	
		Phase III	43	9	52	82.6	
	Total		70	11	81	86.4	
Scan 3	Phase number	Phase II	27	2	29	93.1	
		Phase III	45	7	52	86.5	
	Total		72	9	81	92.5	
Total	Phase number	Phase II	83	4	87	95.4	88.6, 98.7
		Phase III	140	16	156	89.7	83.8, 94.0
	Total		223	20	243	91.7	87.5, 94.9

Is there a tamponade?

Scan 1	Phase number	Phase II	29	-	29	100	
		Phase III	52	-	52	100	
	Total		81	-	81	100	
Scan 2	Phase number	Phase II	29	-	29	100	
		Phase III	49	3	52	94.2	
	Total		78	3	81	96.2	
Scan 3	Phase number	Phase II	27	2	29	96.5	
		Phase III	47	5	52	90.3	
	Total		74	7	81	91.3	
Total	Phase number	Phase II	85	2	87	97.7	91.9, 99.7
		Phase III	148	8	156	94.8	90.1, 97.7
	Total		233	10	243	95.8	92.5, 98.0

Evaluate LV Squeeze

Scan 1	Phase number	Phase II	18	11	29	62.0	
		Phase III	21	31	52	40.3	
	Total		39	42	81	92.8	

Scan 2	Phase number	Phase II	23	6	29	79.3	
		Phase III	44	8	52	84.6	
	Total		67	14	81	82.7	
Scan 3	Phase number	Phase II	24	5	29	82.7	
		Phase III	49	3	52	94.2	
	Total		73	8	81	90.1	
Total	Phase number	Phase II	65	22	87	74.7	64.2, 83.4
		Phase III	114	42	156	73.0	65.4, 79.8
	Total		179	6	243	73.6	68.1, 79.1

Are The Vales Moving

Scan 1	Phase number	Phase II	29	-	29	100	
		Phase III	52	-	52	100	
	Total		81	-	81	100	
Scan 2	Phase number	Phase II	29	-	29	100	
		Phase III	52	-	52	100	
	Total		81	-	81	100	
Scan 3	Phase number	Phase II	29	-	29	100	
		Phase III	51	1	52	98.0	
	Total		80	1	81	98.7	
Total	Phase number	Phase II	87	-	87	100	95.8, 100
		Phase III	155	1	156	99.3	96.4, 99.9
	Total		242	1	243	99..3	96.4, 99.9

Further evaluation of interpretation by scan view (Table 28) shows minimal no errors in the subcostal view for scans 1-2, however scan 3 showed eight errors (88.4%, 95% CI [80.8, 95.9]). The additional apical and parasternal views showed no errors.

Table 28

Pericardial Effusion and Tamponade Interpretation by View and Scan Number

Is there a pericardial effusion?				
Scan view		*n*	%	95% CI
Subxiphoid	Scan 1	80 / 80	100.0	95.4, 100
	Scan 2	66 / 77	85.7	75.8, 92.6
	Scan 3	61 / 69	88.4	78.4, 94.8
Apical	Scan 1	1 / 1	100.0	0.25, 100
	Scan 2	1 / 1	100.0	0.25, 100
	Scan 3	9 / 9	100.0	66.3, 100
Parasternal	Scan 2	3 / 3	100.0	29.2, 100
	Scan 3	2 / 2	100.0	15.8, 100
Is there a tamponade?				
Subxiphoid	Scan 1	80 / 80	100.0	95.4, 100
	Scan 2	74 / 77	96.1	89.0, 99.1
	Scan 3	63 / 69	91.3	82.0, 96.7
Apical	Scan 1	1 / 1	100.0	0.25, 100
	Scan 2	1 / 1	100.0	0.25, 100
	Scan 3	9 / 10	90.0	55.5, 99.7
Parasternal	Scan 2	3 / 3	100.0	29.2, 100
	Scan 3	2 / 2	100.0	15.8, 100

4.4.3 Cardiac Tamponade

In phase II, out of the 87 interpretations, 85 (97.7%, 95% CI [91.9,99.7]) were correct and showed no evidence of tamponade. However, two interpretations were incorrect, suggesting that there were false positives in identifying tamponade. In phase III, out of the 156 interpretations, 148 (94.8%, 95% CI [90.1, 97.7]) were correct, and eight were incorrect. This indicates a slightly lower accuracy rate compared to phase II, but most interpretations

were accurate. Additionally, the analysis revealed a similar pattern as with pericardial effusion as shown in Table 28 where the error in interpretation increased as the scan series progressed. Specifically, phase II had two errors of interpterion in scan 3 and in phase III three and five errors for scans 2-3. Overall, for both phases the total of correct interpretations (no tamponade physiology) was 233 of 243 scans (95.8%, 95% CI [92.5, 98.0]). Evaluating the interpretation by scan view shows no errors in all first scans however the subcostal view scan two shows 74 of 77 correct scans (96.1%, 95% CI [89.0, 99.1]) and scan three shows 63 of 69 correct scans (91.3%, 95% CI [82.0, 96.7]). The apical and parasternal views were mostly correct with one incorrect interpretation for the apical view on scan three.

4.4.4 Left Ventricular Squeeze

In phase II, out of the total 87 interpretations 65 (74.7%, 95% CI [64.2, 83.4]) were correct in evaluating left ventricular squeeze. In phase III, out of the total interpretations 114 (73%, 95% CI [65.4,79.8]) were correct, while 42 interpretations were incorrect. The data indicates that there was a noticeable frequency of incorrect interpretations. Additionally, as shown in Table 28 scan 1 had vigorous squeeze progressing to scan three with no squeeze. As the participants' progressed through the scan series interpretation improved from 48.8% to 94.2%.

When evaluating individual scans (1-3) by phase as shown in Table 29 scans 1-2 in both phases show a high proportion of error with 48.7% (95% CI [37.4, 60.1]) correct interpretations which improved for subsequent scans to 81.8% (95% CI [71.3, 89.6]) and 94.2% (95% CI [85.8, 95.4]) respectively. Of note the progression from scan 1-3 demonstrates vigorous left ventricular squeeze compared to weak and no squeeze.

Table 29

Left Ventricular and Valvular Movement Interpretation by View and Scan

Scan view		*n*	%	95% CI
Evaluate LV squeeze?				
Subxiphoid	Scan 1	39 / 80	48.7	37.4, 60.1
	Scan 2	63 / 77	81.8	71.3, 89.6
	Scan 3	65 / 69	94.2	85.8, 98.4
Apical	Scan 1	1 / 1	100.0	0.25, 100
	Scan 2	1 / 1	100.0	0.25, 100
	Scan 3	6 / 10	60.0	26.2, 87.8
Parasternal	Scan 2	3 / 3	100.0	29.2, 100
	Scan 3	2 / 2	100.0	15.8, 100
Are the valves opening?				
Subxiphoid	Scan 1	80 / 80	100.0	95.4, 100
	Scan 2	77 / 77	100.0	95.3, 100
	Scan 3	69 / 69	100.0	94.7, 100
Apical	Scan 1	1 / 1	100.0	0.25, 100
	Scan 2	1 / 1	100.0	0.25, 100
	Scan 3	9 / 10	90.0	55.5, 99.7
Parasternal	Scan 2	3 / 3	100.0	29.2, 100
	Scan 3	2 / 2	100.0	15.8, 100

4.4.5 Valves Opening

In phase II, all 87 (100%, 95% CI [95.8, 100]) interpretations were correct in evaluating valve opening. In phase III, 155 (99.3%, 95% CI [96.4, 99.9]) interpretations were correct, with one incorrect answer. The results indicate a high accuracy rate in evaluating valve opening. Furthermore, the analysis suggests that echo view or scan number did not account for errors in interpreting valves opening as highlighted in Table 29.

A cross-tabulation analysis of the CAFE exam interpretation by phase and scan number shown in Table 30 reveals a progression in correct interpretation percentages across scans in phase II (62.0%, 72.4%, and 79.3%). Phase III exhibited a lower percentage for the first scan (40.3%) compared to phase II, possibly due to performance and knowledge recall weakening over the 1-month period. Subsequent scans in phase III showed improved interpretation (75.0%, 80.7%), similar to phase II. Scan one had the lowest correct interpretation rate across phases II and III, indicating challenges early on that improved over time.

Table 30

Cross-tabulation Analysis of CAFE Exam Interpretation by Phase and Scan Number

			Interpretation overall				
Phase number			Correct	Incorrect	Total	%	95% CI
Phase II	Scan number	Scan 1	18	11	29	62.0	
		Scan 2	21	8	29	72.4	
		Scan 3	23	6	29	79.3	
	Total		62	25	87	71.2	60.5, 80.4
Phase III	Scan number	Scan 1	21	31	52	40.3	
		Scan 2	39	13	52	75.0	
		Scan 3	42	10	52	80.7	
	Total		102	54	156	65.3	57.3, 72.8
Total	Scan number	Scan 1	39	42	81	48.1	
		Scan 2	60	21	81	74.0	
		Scan 3	65	16	81	80.2	
	Total		164	79	243	67.4	61.2, 73.3

In summary, of the combined CAFE exam interpretation results in phase II, 62 (71.2%, 95% CI [60.5, 80.4]) evaluations were correct in all areas of interpretation. In phase III, 102 (65.3%, 95% CI [57.3, 72.8]) were correct in all areas of interpretation. Of the 243 interpretations, 164 (67.4%, 95% CI [61.2,73.3]) answered all questions correctly. Of note, the scan view presents different results, which have not been investigated due to the limited data in this series.

4.4.6 External Reviewer Reference Scan Interpretation

External reviewers (A and B) interpreted the reference scan series using the CAFE exam providing a benchmark of expert interpretation. Of the 18 images reviewed, nine in phase II and nine in phase III, each reviewer submitted 36 answers per phase. For phase II images, substitute scan three (PSLA view), reviewer A incorrectly identified ventricular squeeze and valvular opening. Reviewer A for the phase III images had no incorrect interpretations. Reviewer B for the phase II scans incorrectly identified ventricular squeeze in scan two (SC4 view) and scan one (PSLA view). Reviewer B also incorrectly identified ventricular squeeze in the phase III scan one (SC4 view and PSLA) images. Reviewer substitute scan results are shown in Table 31.

Overall, most of the incorrect interpretation involved the evaluation of left ventricular squeeze (n = 5). There were two incorrect evaluations of valvular movement interpretation: a myocardial ‘twitch’ and not true valvular activity indicating no forward flow of blood and thus no movement. The combined results for phase II and III reviewer interpretations shows 94-96% of correct interpretation between phases II and III.

Table 31

Cross-tabulation of Reviewer A and B Substitute Scan Interpretation

		CAFE Exam Questions					
Phase II		Is there a pericardial effusion?	Is there a tamponade?	Evaluate LV squeeze	Are the valves opening?	Combined Total	Combined %
Reviewer A	Correct	9	9	8	8	34	94%
	Incorrect	-	-	1	1	2	
Reviewer B	Correct	9	9	7	9	34	
	Incorrect	-	-	2	-	2	
	Total	18	18	18	18	72	100%
Phase III							
Reviewer A	Correct	9	9	9	9	36	96%
	Incorrect	-	-	-	-	-	
Reviewer B	Correct	9	9	7	8	33	
	Incorrect	-	-	2	1	3	
	Total	18	18	18	18	72	100%

4.5 Research Question Four: Underpinning Knowledge

A descriptive analysis of quiz scores in phase II showed a mean score of 9.2 (M = 10, SD = 2.4) and Phase III 10.2 (M = 10.9, SD = 1.5). The minimum scores for phases II and III were 3.6 and 6.5 with a maximum score of 12 for both phases as shown in Table 32.

Table 32

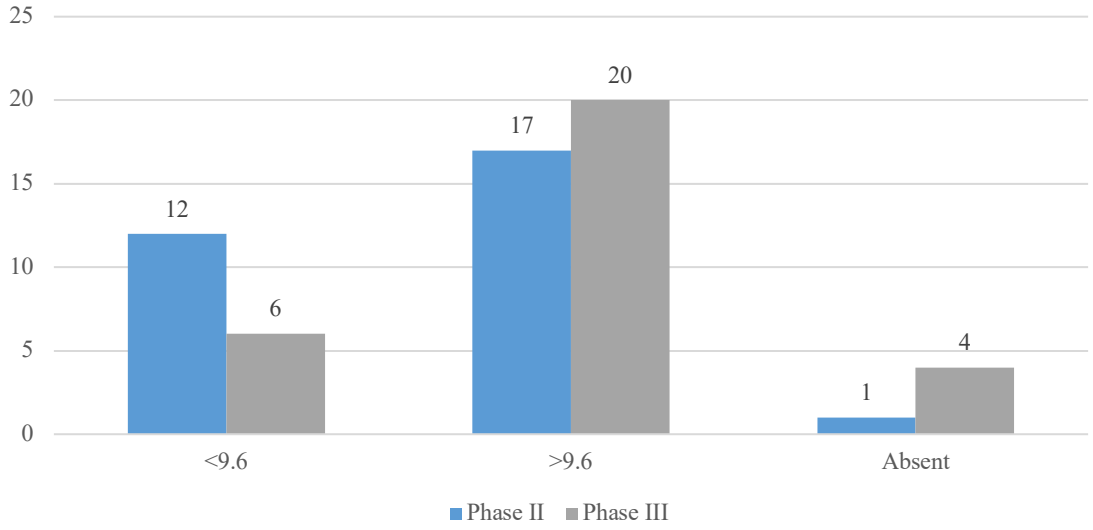
Knowledge Quiz Test Score Frequencies

	Quiz Phase II	Quiz Phase III	Overall (II and III)
Valid	29	26	55
Missing	1	4	5
Mean	9.2	10.2	9.7
Median	10	10.9	10.5
Std. Deviation	2.4	1.5	2.1
Minimum	3.6	6.5	3.6
Maximum	12	12	12

In phase II, 17 out of 29 (58.6%, 95% CI [40.7, 76.5]) participants completed the quiz with an individual passing grade of ≥ 80%, and one participant received a perfect score of 12 shown graphically in Figure 54. Phase III results showed that 20 out of 26 participants (76.9%, 95% CI [60.7, 93.1]) individually passed, with four participants receiving a perfect score. Overall, 67.2% (95% CI [53.2, 79.3]) passed, not meeting the study aim.

Figure 54

Knowledge Quiz Pass Mark Phases II and III



Individual participant test scores tended to improve between phases II and III as shown in Table 33. However, it is worth noting that of the 26 who completed phase III, six participants demonstrated a poorer performance in phase III, as shown in Figure 55.

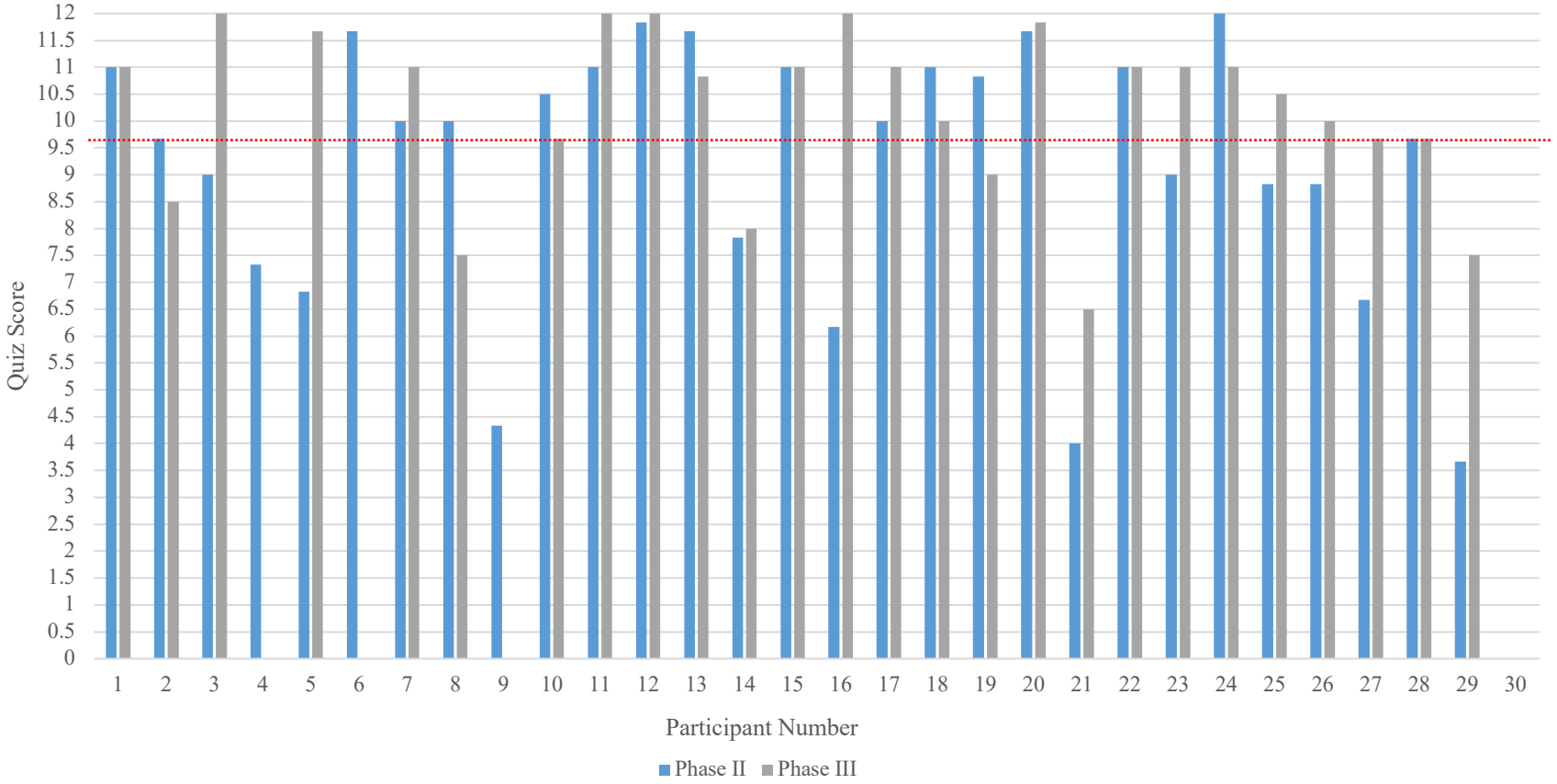
Table 33

Individual Participant Knowledge Quiz Scores Phases II and III

Participant Study ID	Phase II Knowledge Quiz	Phase III Knowledge Quiz
Participant 01, Study	11	11
Participant 02, Study	9.67	8.5
Participant 03, Study	9	12
Participant 04, Study	7.33	-
Participant 05, Study	6.83	11.67
Participant 06, Study	11.67	-
Participant 07, Study	10	11
Participant 08, Study	10	7.5
Participant 09, Study	4.33	-
Participant 10, Study	10.5	9.67
Participant 11, Study	11	12
Participant 12, Study	11.83	12
Participant 13, Study	11.67	10.83
Participant 14, Study	7.83	8
Participant 15, Study	11	11
Participant 16, Study	6.17	12
Participant 17, Study	10	11
Participant 18, Study	11	10
Participant 19, Study	10.83	9
Participant 20, Study	11.67	11.83
Participant 21, Study	4	6.5
Participant 22, Study	11	11
Participant 23, Study	9	11
Participant 24, Study	12	11
Participant 25, Study	8.83	10.5
Participant 26, Study	8.83	10
Participant 27, Study	6.67	9.67
Participant 28, Study	9.67	9.67
Participant 29, Study	3.67	7.5

Figure 55

Individual Participant Knowledge Quiz Scores Phase II and III



Note. Red line indicates the required pass mark of 9.6 out of 12 or ≥ 80%.

4.5.1 Knowledge Quiz Score Distribution

A Shapiro-Wilk test of normality showed that quiz scores from phases II and III do not follow normal distribution ($p = 0.05$) as shown in Table 34. A Quantile-Quantile plot and Shapiro-Wilk histogram is shown in Figure 56.

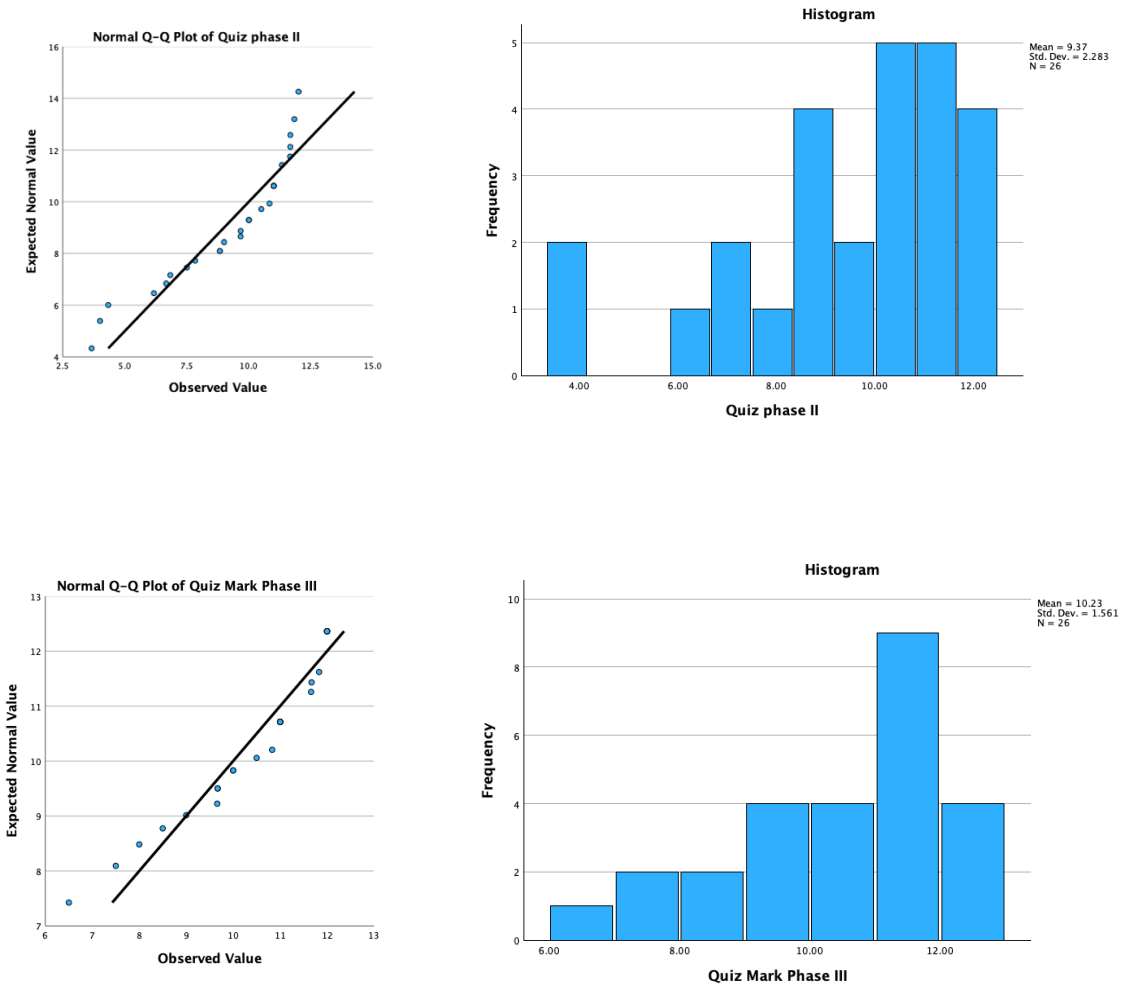
Table 34

Shapiro-Wilk Test of Normality

	Statistic	df	Sig.
Quiz phase II	0.874	26	0.004
Quiz phase III	0.894	26	0.012

Figure 56

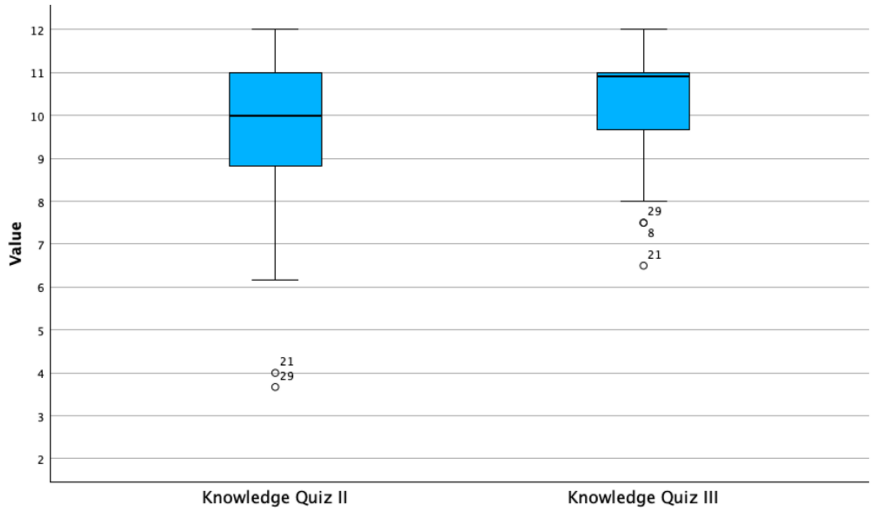
Quantile-Quantile Plot and Shapiro-Wilk Histogram of Knowledge Quiz Distribution



A box and whisker graph of phases II and III knowledge quiz scores highlights the distribution as shown in Figure 57.

Figure 57

Box and Whisker Graph Knowledge Quiz Distribution for Phases II and III



4.5.2 Wilcoxon Signed Rank Test

The Wilcoxon Signed Rank Test showed phase II and III knowledge quiz scores had no statistical difference in improvement ($p = 0.051$) as shown in Table 35.

The effect size was calculated using the Z value (1.950) divided by the square root of 26, resulting in 0.382, which is defined as a medium effect size (Pallant, 2020). This indicates that the improvement had practical significance and relevance to genuine improvement in knowledge retention. Such findings support the argument for periodic training sessions to reinforce and enhance knowledge.

Table 35

Related-Samples Wilcoxon Signed Rank Test

Related-Samples Wilcoxon Signed Rank Test Summary	
Total N	26
Test Statistic	186.500
Standard Error	30.757
Standardized Test Statistic	1.951
Asymptotic Sig.(2-sided test)	0.051

4.5.3 Individual Knowledge Quiz Questions

Question One. Participants were asked to select which echo view was shown in a 3-second video clip. The SC4 view was the correct answer. In phase II, 27 (93.1%, 95% CI [77.2, 99.1]) participants answered this question correctly, with two incorrect answers. In phase III, there were 23 (88.4%, 95% CI [69.8, 97.5]) correct answers and three wrong answers. The PSLA was selected by participants for all the incorrect answers. Results are shown in Figure 58.

Question Two. Participants labelled structures shown on a SC4 view. In phase II, the question was answered correctly by 28 (96.5% 95% CI [82.2, 99.9]) participants, with one incorrect answer. This study participant mislabelled the pericardium and left atrium. One wrong selection for this answer resulted in zero points. In phase III, 26 (100%, 95% CI [86.77, 100]) participants correctly labelled the sonographic structures. Results are shown in Figure 58.

Question Three. Participants were asked to match colours and numbers on a parasternal long-axis anatomy view. This question was worth one point; if one label was incorrect, the answer was marked as wrong. Many participants had partially correct answers,

but the question is worth one point only. In phase II, question three was answered correctly by 10 (34.4%, 95% CI [17.9, 54.3]) participants and incorrectly by 19. In phase III, 18 (69.2%, 95% CI [48.2, 85.6]) participants responded to the question correctly, with eight incorrect answers. Results are shown in Figure 58.

Question Four. Participants were asked to match the image displayed with the correct view. This question was awarded one point. In phase II, question four was answered correctly in 29 (100%, 95% CI [95.8, 100]) answers. In phase III, 22 (84.6%, 95% CI [65.1, 95.6]) were correct, with four incorrect answers. Results are shown in Figure 58.

Question Five. Participants were to identify which echo the view of the heart shown. This question was worth one point. In phase II, 24 (82.7%, 95% CI [64.2, 94.1]) answers were correct, with five incorrect answers. In phase III, 24 (92.3%, 95% CI [74.8, 99.0]) answers were correct, with two wrong answers. Results are shown in Figure 58.

Question Six. Participants were asked to match the colours and numbers with the correct labels in an A4C view. This question was worth one point; if one title was mismatched, the answer was marked as incorrect. Many participants had partially correct answers, but all correct answers were worth one point. In phase II, 20 (68.9%, 95% CI [49.1, 84.7]) answered correctly and nine incorrectly. In phase III, 22 (84.6%, 95% CI [65.1, 95.6]) were correct, and four were incorrect. Results are shown in Figure 58.

Question Seven. Participants had to match the four sentences with the correct answer concerning CAFE exam integration. In phase II, 25 (86.2%, 95% CI [68.3, 96.1]) answered correctly and three incorrectly, with one missing an answer included in the total. In phase III, 23 (84%, 95% CI [65.1, 95.6]) were correct, and three were incorrect. Results are shown in Figure 58.

Question Eight. Participants chose the most appropriate answer. This question was worth one point. In phase II, 23 (79.3%, 95% CI [60.2, 92.0]) answered correctly and five incorrectly, with one missing answer included in the total. In phase III, 22 (84.6%, 95% CI [65.1, 95.6]) were correct, and four were incorrect. Results are shown in Figure 58.

Question Nine. Participants had to drag and drop words to complete a sentence about pericardial effusion and tamponade. This question was worth one point for six correct answers. In phase II, 10 (34.3%, 95% CI [17.9, 54.3]) participants answered correctly and 18 incorrectly, with one missing answer included in the total. In phase III, 14 (53.8%, 95% CI [33.3, 73.4]) answers were correct and 12 incorrect. Results are shown in Figure 58.

Question Ten. Participants assessed an ultrasound video clip using the CAFE exam. This question was worth one point. In phase II, 22 (75.8%, 95% CI 56.4,89.7]) answered correctly and five incorrectly, with two missing answers included in the total. In phase III, 21 (80.7%, 95% CI [60.6, 93.4]) were correct, and five were incorrect. Results are shown in Figure 58.

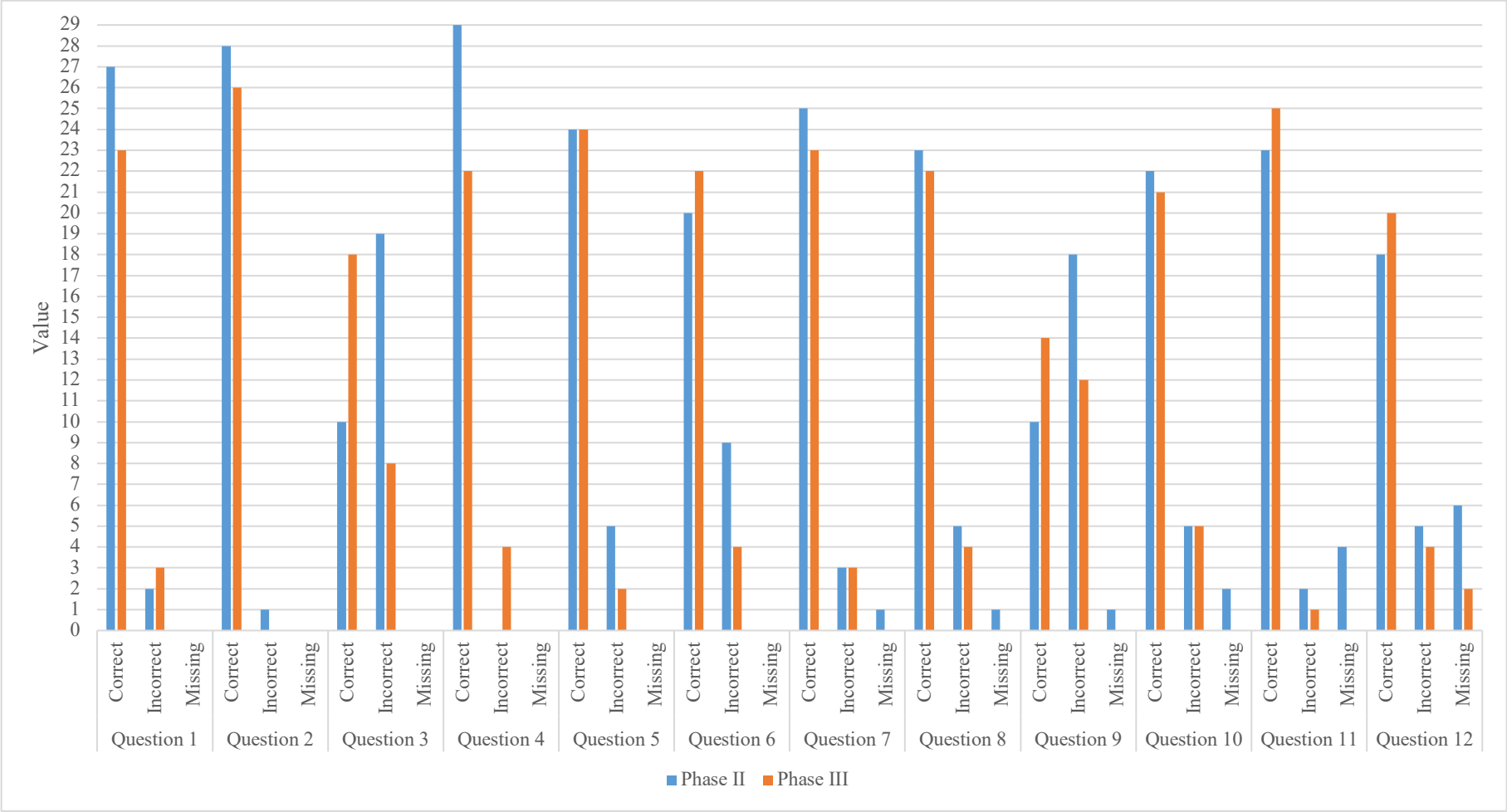
Question Eleven. Participants selected the correct diagnosis for the image shown. This question was worth one point. In phase II, 23 (79.3%, 95% CI [60.2, 92.0]) answered correctly and two incorrectly, with four missing answers included in the total. In phase III, 25 (96.1%, 95% CI [80.3, 99.9]) were correct, and one was incorrect. Results are shown in Figure 58.

Question Twelve. Participants selected the correct diagnosis for the image shown. This question is worth one point. In phase II, 18 (62.0%, 95% CI [42.2, 79.3]) answered correctly and five incorrectly, with six missing answers included in the total. In phase III, 20 (76.9%, 95% CI [56.3, 91.0]) were correct and four incorrect, with two missing answers included in the total. Results are shown in Figure 58.

When comparing individual questions with phase numbers, it becomes evident that questions three, nine and twelve were challenging.

Figure 58

Knowledge Quiz Question by Phase



4.5.4 Refresher Module Participation

The time between phase II and III was 1-month. Twenty-four participants accessed the Canvas module. Of the 12 participants who did not pass the knowledge quiz in phase II, two were absent (due to SARS-CoV-2), seven achieved a pass in phase III, and three did not pass. Three additional participants who previously passed phase II failed in phase III.

4.6 Incidental Findings

4.6.1 Hands-off-time Versus CUSAS Score

In phase II, reviewer A, scored 68 images a CUSAS of ≥ 3, with 27 (39.7%) images taking less than 10 seconds. Reviewer B had similar results, with 61 images a CUSAS of ≥ 3 and 21 (34.4%) taking less than 10 seconds. In phase III, reviewer A scored 128 images a CUSAS of ≥ 3 and 77 (60.1%) taking less than 10 seconds. Reviewer B had similar results with 121 images a CUSAS of ≥ 3 and 72 (59.5%) in less than 10 seconds. Overall, there is an approximate 20% improvement in achieving a CUSAS of ≥ 3 in less than 10 seconds between phases II and III. A crosstabulation analysis showing HOT and CUSAS Score is shown in Table 36.

Table 36

Analysis between Hands-off-time and CUSAS Score

			Rater A		
Phase number			< 3	≥ 3	Total
Phase II	Hands off time	< 10 seconds	4	27	31
		≥ 10 seconds	10	41	51
	Total		14	68	82
Phase III	Hands off time	< 10 seconds	6	77	83
		≥ 10 seconds	18	51	69
	Total		24	128	152
			Rater B		
Phase II	Hands off time	< 10 seconds	10	21	31
		≥ 10 seconds	11	40	51
	Total		21	61	82
Phase III	Hands off time	< 10 seconds	11	72	83
		≥ 10 seconds	20	49	69
	Total		31	121	152

4.6.2 Analysis of Competence

Of the 243 simulation ultrasound scans acquired, 222 (91.3%) were marked competent, and 21 were not yet competent shown in Table 37. Of note, nine of the assessments were deemed not yet competent were from group A with one in group B. Additionally, those with competency failures tended to have additional failures with the scan series.

Table 37

Echo Simulation Competency by Study Participant ID

		Is the study participant competent?		Total
		Yes	No	
Study participant ID	1	6	3	9
	2	5	4	9
	3	6	3	9
	4	3	-	3
	5	8	1	9
	6	2	1	3
	7	9	-	9
	8	6	3	9
	9	2	1	3
	10	9	-	9
	11	8	1	9
	12	9	-	9
	13	6	3	9
	14	9	-	9
	15	9	-	9
	16	9	-	9
	17	9	-	9
	18	9	-	9
	19	9	-	9
	20	9	-	9
	21	9	-	9
	22	9	-	9
	23	9	-	9
	24	9	-	9
	25	9	-	9
	26	9	-	9
	27	9	-	9
	28	9	-	9
	29	8	1	9
Total		222	21	243

A cross-tabulation analysis between phase, simulation and scan number showed the difference in competency between phases II and III as shown in Table 38. There were 76 (87.3%) of participants deemed competent in phase II, with an increase in competence (*n* = 146, 93.5%) in phase III. Notably, phase III simulation stations were not sequential and were assigned to a participant as a station became available.

Table 38

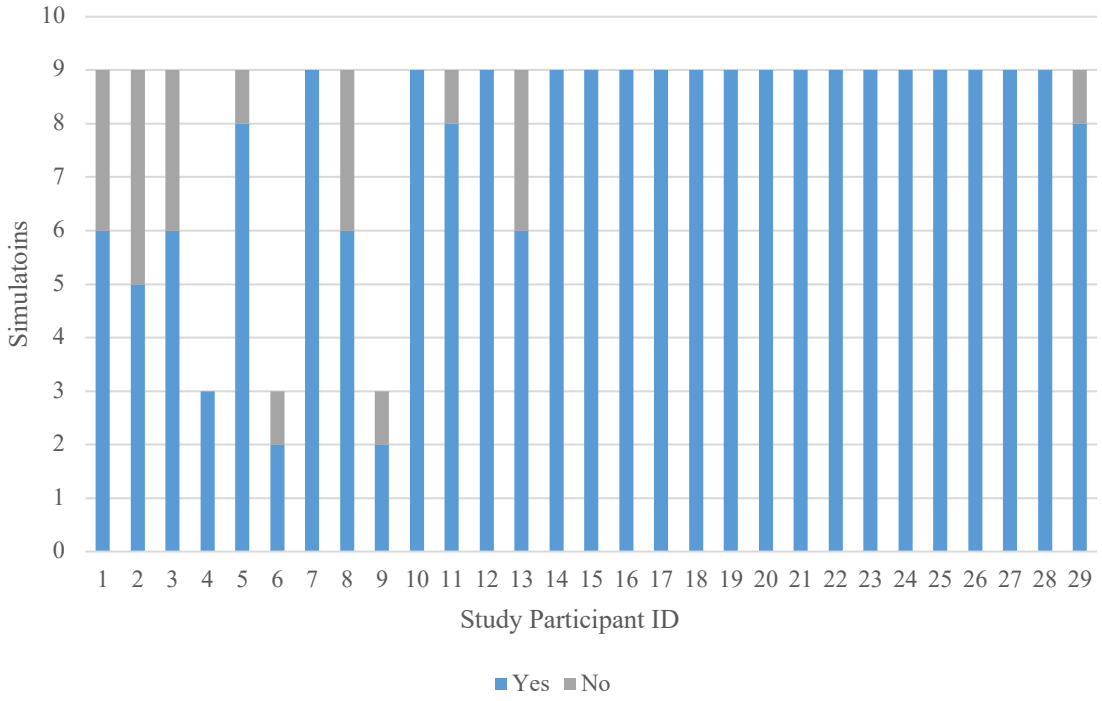
Study Participant Simulation Echo Competency with Scan Number

Phase number		Simulation number		Scan number			
				Scan 1	Scan 2	Scan 3	Total
Phase II	Simulation 1	Is the study participant competent?	Yes	25	25	26	76
			No	4	4	3	11
		Total		29	29	29	87
Phase III	Simulation 1	Is the study participant competent?	Yes	26	26	25	77
			No	-	-	1	1
		Total		26	26	26	78
	Simulation 2	Is the study participant competent?	Yes	21	24	24	69
			No	5	2	2	9
		Total		26	26	26	78

Due to the high percentage of overall simulation scan competency (91.3%), per-person failures in competency show the relationship between the participant and repeated competence failure. Figure 59 highlights study identification numbers one, two, three, eight and thirteen as having greater than three failures for competence. Four participants failed one competency only and did not have repeat failures.

Figure 59

Simulation Competency by Study Participant



4.6.3 Echo View Quality

Of the 243 echo views carried out during simulations, 226 (93%) were taken in the SC4 view, 12 were apical, and five were parasternal views. In phase II, one scan was taken in the apical view for scan one, and there were no parasternal first views. In phase III, all scans commenced in the SC4 view, with one parasternal view in scan two, as shown in Table 39.

Table 39

Frequencies of Simulation Scan View by Phase and Scan Number

Phase number	View	Scan	*n*	%
Phase II	Subxiphoid	Scan 1	28	38.4
		Scan 2	26	35.6
		Scan 3	19	26.0
		Total	73	100.0
	Apical	Scan 1	1	10.0
		Scan 2	1	10.0
		Scan 3	8	80.0
		Total	10	100.0
	Parasternal	Scan 2	2	50.0
		Scan 3	2	50.0
		Total	4	100.0
Phase III	Subxiphoid	Scan 1	52	34.0
		Scan 2	51	33.3
		Scan 3	50	32.7
		Total	153	100.0
	Apical	Scan 3	2	100.0
	Parasternal	Scan 2	1	100.0
Total			243	100.0

4.6.4 Echo Skills Competency

A frequency table displaying echo skills competency is shown by phase and competency question in Table 40.

Subcostal View (Phase II). Twenty-nine participants attained this view of which 26 (89.6%, 95% CI [72.6, 97.8]) were correct, with one participant selecting the incorrect view and two unable to attain a view. Probe orientation was correct in 27 (93.1%, 95% CI [77.2, 99.1]) scans, with one image not attained. The image was central in 25 (92.5%, 95% CI [75.1, 99.0]) cases and no image was attained in two cases. The correct depth was selected in 23 (85.1%, 95% CI [66.2, 95.8]) scans. Twenty-five (92%, 95% CI [75.7, 99.0]) correctly

identified the RV. Moreover, 20 (74.0%, 95% CI [53.7, 88.9]) were able to accurately identify either the mitral or tricuspid valve, and 23 (88.4%, 95% CI [69.8, 97.5]) correctly identified the pericardium.

Apical View (Phase II). Twenty-nine participants (100%, 95% CI [88.0, 100]) attained and used the correct probe orientation. The image was central in 25 (96.1%, 95% CI [80.36, 99.9]) images with one off-axis. Twenty-four (92.3%, 95% CI [74.8, 99.0]) of participants correctly identified the LV with two incorrect answers. The pericardium was correctly identified in 24 (92.3%, 95% CI [74.8, 99.0]) images, with two incorrect answers and three images not attained.

Parasternal Long Axis View (Phase II). Twenty-nine participants attained this view, with one participant not gaining a view. Probe orientation was correct in 29 scans (100%95% CI [88.0, 100]) and the image was central in 28 (96.5%, 95% CI [82.2, 99.9]), with one off-axis image. The correct depth was selected in 21 (72.4%, 95% CI [52.7, 87.2]) scans, with seven incorrect depth selections and one image not attained. Twenty-three (79.3%, 95% CI [60.2, 92.0]) participants correctly identified the LV with five incorrect answers, and 25 (86.2%, 95% CI [68.3, 96.1]) correctly identified the RV with three incorrect answers and one image not attained.

Subcostal View (Phase III). Twenty-six participants completed the repeat echo assessment phase III. Twenty-five (96.1 95% CI [80.3, 99.9]) images were correct in the SC4 view, with one participant choosing the incorrect view. Probe orientation was correct in 23 (88.4%, 95% CI [69.8, 97.5]) scans, with three incorrect probe marker orientations. The image was central in 18 of 21 images (85.7%, 95% CI [63.6, 96.9]), with three off-axis images and two image failures. The correct depth was selected in 21 of 23 (91.3%, 95% CI [71.9, 98.9]) scans with two incorrect. Eighteen of 20 participants correctly identified the RV

and atrioventricular valves (90.0%, 95% CI [68.3, 98.7]), with two incorrect identifications for both. Twenty of 26 answers (76.9%, 95% CI [56.3, 91.0]) were able to correctly identify the pericardium, with six incorrect answers.

Apical View (Phase III). Twenty-six images (100%, 95% CI [86.7, 100]) were correct in the apical view, 22 (84.5%, 95% CI [65.1, 95.6]) participants had the correct probe orientation, with two incorrect. The image was central in 23 of 24 (95.8%, 95% CI [78.8, 99.8]) with one image off-axis. Twenty of 24 (83.3%, 95% CI [62.6, 95.2]) participants correctly identified the LV with four incorrect answers. The pericardium was correctly identified in 23 of 24 (95.8%, 95% CI [78.8, 99.8]) images, with one incorrect answer.

Parasternal Long Axis View (Phase III). Twenty-six images (100%, 95% CI [86.7, 100]) were correct in the parasternal long-axis view. The probe orientation was correct in 21 (80.7%, 95% CI [60.5, 93.4]) scans, with five incorrect. The image was central in 23 of 25 (92.0%, 95% CI [73.9, 99.0]) with two off-axis images. The correct depth was selected in 19 of 25 (76.0%, 95% CI [54.8, 90.6]) of scans, with six incorrect depth selections and two images not attained. Twenty of 25 (80.0%, 95% CI [59.3, 93.1]) correctly identified RV with five incorrect answers. Nineteen (76.0%, 95% CI [54.8, 90.6]) participants correctly identified the LV with six incorrect answers.

Table 40

Echo Skills Assessment Competence Phases II and III

		Valid		Correct view*		Probe Orientation		Image Centre		Image Depth		Identify the ventricle				Identify Ventricular Valves		Identify Pericardium	
												Yes RV	No RV	Yes LV	No LV				
Phase II	Echo View	*n*	Miss	Yes	No	Yes	No	Yes	No	Yes	No					Yes	No	Yes	No
	Subxiphoid	29	1	26	1	27	1	25	2	23	4	25	2	-	-	20	7	23	3
	Apical	29	1	29	-	29	-	25	1	-	-	-	-	24	2	-	-	24	2
	Parasternal long axis	29	1	29	-	29	-	28	1	21	7	25	3	23	5	-	-	-	-
	Total	87	3	84	1	85	1	78	4	44	11	50	5	47	7	20	7	47	5
Phase III	Subxiphoid	26	4	25	1	23	3	18	3	21	2	18	2	-	-	18	2	20	6
	Apical	26	4	26	-	22	4	23	1	-	-	-	-	20	4	-	-	23	1
	Parasternal long axis	26	4	26	-	21	5	23	2	19	6	20	5	19	6	-	-	-	-
	Total	78	12	77	1	66	12	64	6	40	6	38	7	39	10	18	2	20	1

Note. Miss = Missing image study participant. Of note, if the participant could not acquire the echo image, the questions could not be answered, resulting in unequal results for each variable, a dash (-) = Not Asked, LV = Left Ventricle, RV = Right Ventricle. *Correct view denotes the correct echo window and does not explain the ultrasound image quality.

These results show that performance levels decreased in phase III, which occurred 1 month after phase II with no additional hands-on training. Participants performed well across many tested variables, however some areas, such as probe orientation, image depth and, to a lesser extent, ventricle identification required additional education and hands-on experience to improve competency. These factors highlight the importance of training and education to maintain competency and confidence in image acquisition.

When combining study ID with competency, CUSAS and HOT shown in Table 41 a pattern emerges. Study participants who received a CUSAS score of < 3 was more likely to be deemed not yet competent. In contrast, Group B (participants 16 to 29) do not show a clear pattern with participant 29 having mixed results.

Table 41

Cross-tabulation of Study ID with Competency, CUSAS and Hands-off Time

	Is the study participant competent?		Total	Rater A (Binned)			Total	Hands-off Time		Total
Study ID	Yes	No		No Image	< 3	≥ 3		< 10	≥ 10	
1	6	3	9	-	3	6	9	-	9	9
2	5	4	9	-	4	5	9	-	9	9
3	6	3	9	3	4	2	9	1	8	9
4	3	-	3	-	3	-	3	-	3	3
5*	8	1	9	-	3	6	9	1	8	9
6*	2	1	3	2	-	1	3	-	3	3
7	9	-	9	2	3	4	9	7	2	9
8	6	3	9	-	-	9	9	4	5	9
9*	2	1	3	-	2	1	3	-	3	3
10	9	-	9	-	1	8	9	1	8	9
11*	8	1	9	-	1	8	9	8	1	9
12	9	-	9	-	1	8	9	8	1	9
13	6	3	9	-	-	9	9	-	9	9
14	9	-	9	-	6	3	9	5	4	9
15	9	-	9	-	1	8	9	5	4	9
16	9	-	9	-	-	9	9	6	3	9
17	9	-	9	-	-	9	9	4	5	9
18	9	-	9	-	1	8	9	2	7	9

19	9	-	9	-	-	9	9	5	4	9
20	9	-	9	-	1	8	9	8	1	9
21	9	-	9	-	1	8	9	4	5	9
22	9	-	9	-	-	9	9	4	5	9
23	9	-	9	-	-	9	9	8	1	9
24	9	-	9	-	-	9	9	7	2	9
25	9	-	9	-	-	9	9	6	3	9
26	9	-	9	-	2	7	9	6	3	9
27	9	-	9	-	2	7	9	3	6	9
28	9	-	9	-	-	9	9	9	-	9
29*	8	1	9	-	1	8	9	4	5	9
Total	222	21	243	7	40	196	243	116	127	243

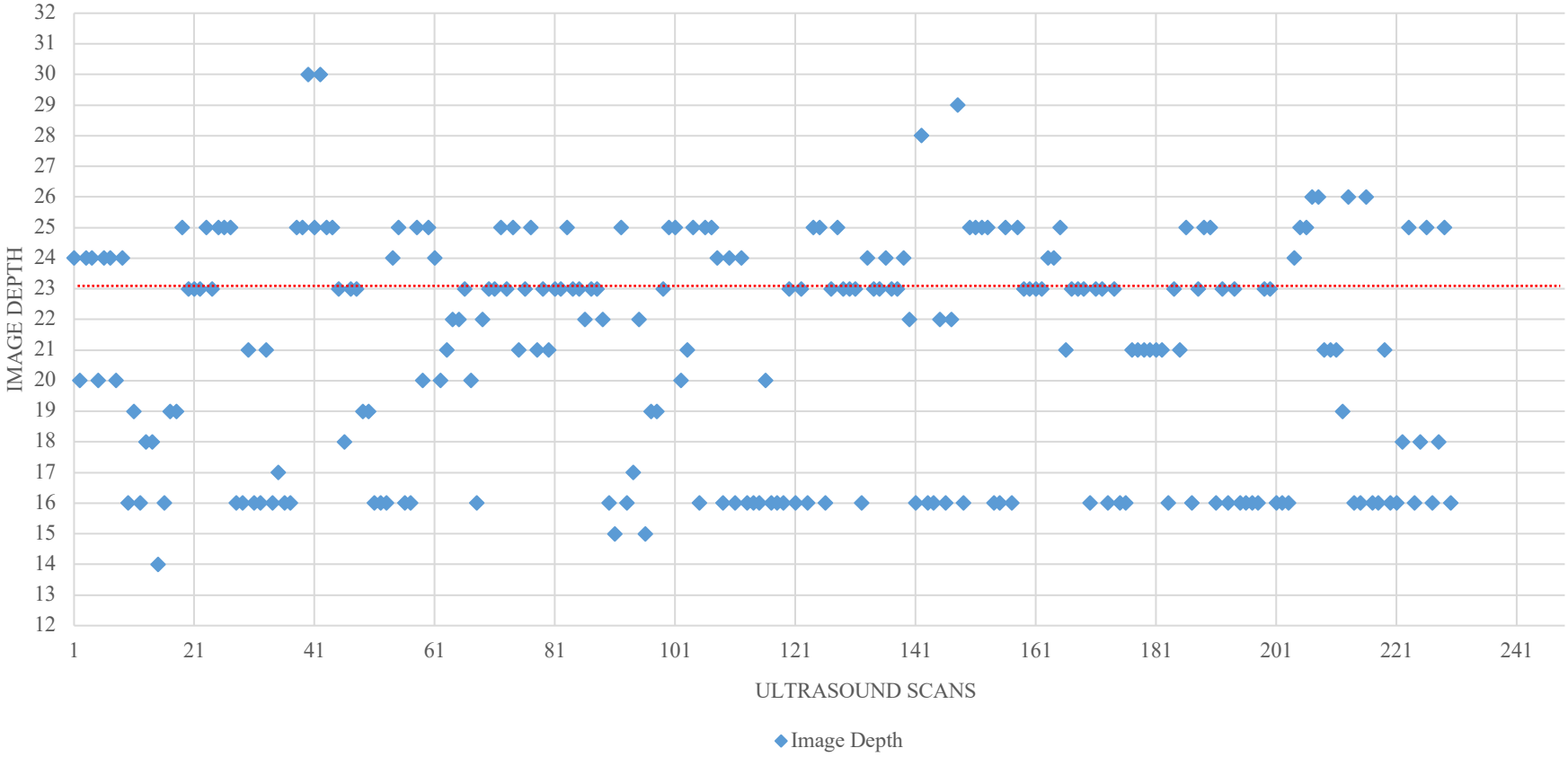
Note. Grey highlight indicates study participants who had repeated competency failures. *Indicates study participants who had one competency failure.

4.6.5 Ultrasound Image Depth Selection

Of the 230 images in phase II and III simulations, the mean depth selected was 20.9 cm (M = 22, SD = 3.7), with a minimum and maximum depth between 14 and 30 cm. The most common selection was 16 cm, with 63 (27.3%) participants selecting this depth over repeated measures. However, a large group selected between 23 and 25 cm (n = 104, 45.2%), as shown in Figure 60.

Figure 60

Ultrasound Image Depth Selection for Simulations in Phases II and III

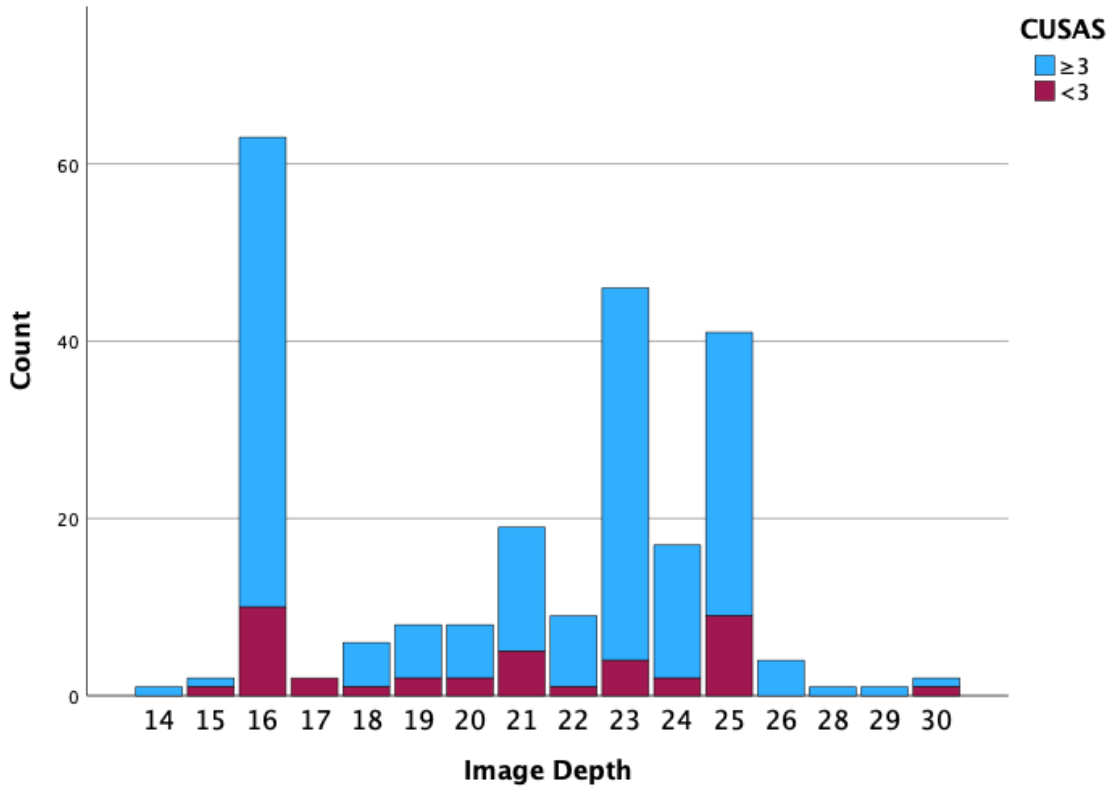


Note. Red line highlights the 23 cm depth setting.

During this analysis, it became apparent that there may be a potential relationship between the CUSAS score and selected image depth. However, the two variables have no clear link, as shown in Figure 61. Of note, the depth selection of 16, 21, 23 and 25 was associated with a higher proportion of CUSAS scores of ≥ 3. The anomaly at 16 cm may be attributed to the characteristics of the young adult healthy volunteers.

Figure 61

CUSAS and Image Depth



Note. CUSAS scoring is from Reviewer A.

To further investigate the apparent non-relationship, a Spearman's rank-order correlation analysis was performed to determine the degree of relationship between image depth and simulation CUSAS score. Reviewer A was used as the reference, and a one-tailed test looked for increases or decreases within the data set shown in Table 42.

Table 42

Spearman's Rho Reviewer A Simulation CUSAS with Image Depth Phases II and III

			Reviewer A sim CUSAS	Image Depth all phases
Spearman's rho	Reviewer A sim CUSAS	Correlation Coefficient	1.000	-0.024
		Sig. (1-tailed)	-	0.357
		n	243	230
	Image Depth all phases	Correlation Coefficient	-0.024	1.000
		Sig. (1-tailed)	0.357	-
		n	230	230

The results show no significant correlation between CUSAS score and image depth from reviewer A, r(230) = -0.02, p = 0.357. These results suggest that the CUSAS score is not influenced by image depth. Notwithstanding this, selecting the correct image depth should be considered part of standard image optimisation with echo scanning convention selecting less than 21 cm in the SC4 view as improving the chances of capturing an image of the heart. The study population of heterogeneous healthy volunteers is narrow, which may limit the generalisability of these findings.

This chapter has provided results to the research questions. The discussion interprets the findings, relates back to the literature, and provides clinical context to the research questions.

Chapter 5 Discussion

This research sought to determine if paramedics could acquire and interpret an ultrasound image during pulse check pauses in simulated PEA cardiac arrest scenarios. Secondary aims focused on ultrasound image acquisition, interpretation, and retention of learned knowledge.

This chapter explores the key findings for each research question and the contribution of new information relevant to the existing literature. The goal was to enhance current knowledge and safely integrate ultrasound into OHCA care. The significance and relevance of the findings are discussed within the context of clinical implications in PEA cardiac arrest, as well as the possible future direction of this research. Key findings are summarised, identifying correlations, patterns, and relationships within prior studies, and their significance is evaluated and discussed. This chapter offers practical suggestions for future research and highlights the study's strengths and weaknesses while acknowledging limitations.

5.1 Key Findings

The study reveals an average HOT of 9.6 (95% CI [9.3, 10.0]) seconds and a median of 10.0 seconds during simulated cardiac arrest resuscitations. Nearly half (47.7%) of all ultrasound scans were completed in under 10 seconds. As for image quality, reviewers A and B agreed on a CUSAS of ≥ 3 for 173 cases (73.9%, 95% CI [67.8, 79.4]) which did not meet the desired standard of ≥ 3 in 90% of cases. Paramedic CAFE exam scan interpretation accuracy for phase II was 91.9% (95% CI [88.5, 94.5]), and phase III 89.2% (95% CI [86.5, 91.5]) meeting the study aim of 90%. In the knowledge quiz, 58.6% (95% CI [40.7, 76.5]) participants completed the quiz with an individual passing grade of ≥ 80% and in Phase III 76.9% (95% CI [60.7, 93.1]) not meeting the study aim of ≥ 80%.

5.2 Research Question One Discussion: Image Acquisition

The first research question aimed to determine whether 100% of paramedics could perform ultrasound within the 10 second pulse check pause during simulated cardiac arrest resuscitations at least 90% of the time. The study reported a mean HOT of 9.6 seconds (95% CI [9.3, 10.0]) across phases II and III. The narrow confidence interval suggests on average paramedics performed ultrasound within the 10 second window. However, the HOT data in performance shows variability with outlier scan times. Contrary to expectations only 47.7% (95% CI [41.3, 54.2]) of the scans met the < 10 second criterion. There was a 17% improvement in achieving < 10 seconds between phases II and III possibly due to knowledge consolidation and reduced assessment load in phase III.

Notably, nearly 20% (19.3%, 95% CI [14.5, 24.8]) of scans were completed just 1-second beyond the 10 second cut-off, suggesting that minor adjustments could increase the percentage of scans completed within the target timeframe.

The aggregation of individual studies reveals notable variations in HOT outcomes across different research contexts. These disparities underscore the importance of considering methodological subtleties and study populations when interpreting HOT data. A British study assessed 10 paramedics, with findings indicating that 96.7% of echo scans (n = 29 of 30) were completed within 10 seconds (Younger et al., 2016). This efficiency rate is notably higher than the results of the CAFE trial, which reported 47.7% of scans completed within 10 seconds.

It is important to recognise the methodological differences between these two studies that might have influenced these outcomes. The study by Younger et al. (2016) relied on an ultrasound simulator mannequin, which, while useful for basic training, lacks real human

anatomy. In contrast, the CAFE trial utilised healthy volunteer models, ensuring high simulation fidelity and mirroring authentic clinical scenarios more closely. Such realism is indispensable, particularly when contextualised against the demanding and critical nature of cardiac arrest resuscitation. Furthermore, the Younger study had a more limited scope, given its smaller sample size and 30 HOT measurements, whereas the CAFE trial had 243. In comparison, the CAFE trial placed more emphasis on simulation realism and fidelity, offering deeper insights into how ultrasound is employed in operational environments. An enhanced understanding is crucial for comprehending the role of ultrasound in OHCA resuscitation and potentially refining the resuscitation process in the future.

Drawing from the literature, the successful implementation of echocardiography within the critical 10 second window during cardiac arrest (94.7%, n = 36 of 38), as demonstrated by the Prehospital Echocardiography in Cardiac Arrest (PECA) trial (Kreiser et al., 2022). In this trial, 40 paramedics received didactic lectures and practical training aimed at acquiring and interpreting essential cardiac arrest echo views. The educational focus of the PECA trial evaluated ventricular contractility, pericardial effusion, and pneumothorax. However, an important consideration arises from the trial's description of scan acquisition as a 'compression pause' without clear details on measurement capture methods. Comparatively, Gaspari et al. (2021) reported substantial variation in their study data particularly an 8 second disparity between CPR pause length (28.3 seconds) and ultrasound acquisition time (20.4 seconds), underscoring the necessity of precisely defining measurement parameters in research. Such discrepancies have implications for data interpretation and comparability across studies within the broader literature.

While drawing comparisons between Younger et al. (2016) and the PECA trial, it is encouraging to note that both reported excellent adherence to the 10 second pulse check

pause. The absence of standardised HOT measurements introduces ambiguity, making it challenging to directly compare their results with those of the CAFE study. Both trials showed promising results for ultrasound acquisition, particularly the PECA trial, performed in the operational setting with paramedics.

Another key study is that produced by Gaspari et al. (2021), who reported a mean HOT of 13.1 seconds (95% CI [12.1, 14.2]) using a pre-imaging technique within a controlled ED environment. Surprisingly, despite the controlled setting, the observed HOT was longer compared to the PECA prehospital trial, suggesting potential influences of ED-specific factors such as access to a wider array of resources. The disparity in HOT between ED and prehospital settings underscores the impact of environmental variations, including staff availability and physical challenges encountered in the field. While the CAFE trial demonstrated paramedic performance in simulated prehospital scenarios, Gaspari et al. findings highlight the necessity of customizing scanning protocols to suit the unique demands of different settings (Gaspari et al., 2021).

Shifting the focus to the minimum and maximum HOT durations of the CAFE trial, in the current study, the findings yielded surprisingly short HOT. The minimum in phases II and III was 4.6 and 3.9 seconds respectively. Although a short HOT is preferable for improving CCF, it is important to note that a quick scan may not capture the entire cardiac cycle or slow heartbeat required to evaluate left ventricular function (squeeze) and valvular movement in the CAFE exam. In contrast, evaluating fluid for pericardial effusion doesn’t require a complete cardiac cycle if the ultrasound view is sufficient. Meanwhile, accurately diagnosing the severity of the obstructive shock, such as tamponade physiology, calls for a more comprehensive ultrasound image capturing multiple heartbeats to analyse right ventricular wall motion.

In reviewing the CAFE HOT durations, a comparison observation emerged. The maximum HOT durations for phases II and III were 27.3 seconds and 14.8 seconds, respectively. These findings closely align with Gaspari et al. (2021), who documented a maximum HOT of 33.1 seconds pre-intervention. Notably, after implementing their pre-imaging technique, they observed a reduction in the maximum HOT to 14.2 seconds. It is essential to highlight research by Gaspari et al. (2021) occurred in the ED and involved trained ultrasound doctors. In contrast, the CAFE study setting centred around ultrasound-naive paramedics and incorporated the pre-imaging technique from the outset.

The simulation environment was useful for evaluating factors contributing to meeting the target of less than 10 seconds. It was observed that phase II simulation station three exhibited a significantly higher likelihood of a prolonged HOT when compared to other stations (UOR = 7.1, 95% CI [2.12, 25]. Even when accounting for individual participant variations, the association strengthened with the odds increasing to 7.69 (95% CI [1.35, 9.09]).

The simulation environment assisted in identifying which station was more likely to lead to longer HOT durations. The characteristic variable in station three included a healthy female volunteer described by the assessor as ‘tall with difficult echo views’, specifically the SC4 view used for most simulation scan attempts. The relationship between echo view difficulty and increased HOT is apparent when reviewing the reference scans taken by the assessors on healthy models before simulations commenced. External reviewers A and B evaluated the assessor’s scans using the CUSAS. Notably, the reference scans for phase II simulation station three exhibited CUSAS scores of one and four in the SC4 view and a six on the third attempt in the apical view. The still images of the assessor scans in Figure 62 illustrates the challenging nature of the healthy volunteer’s echo views. It is essential to

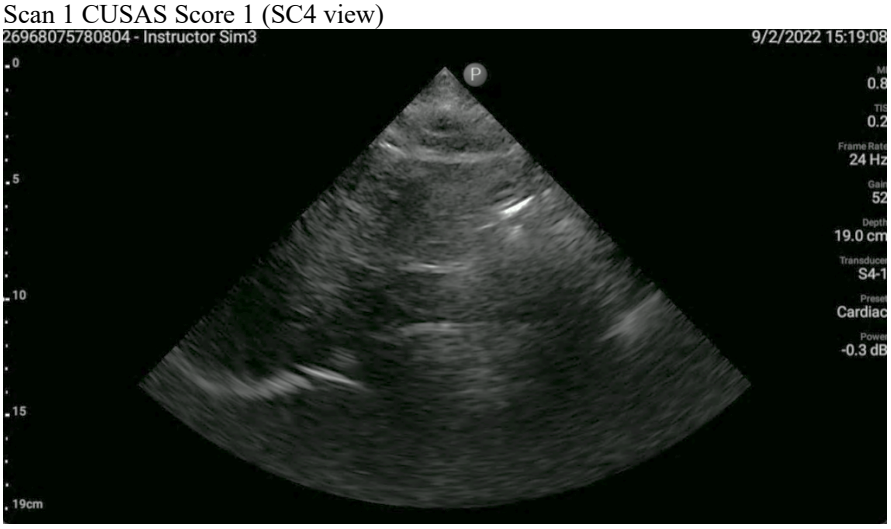
mention the assessor scan series was acquired by the assessor within a 10 to 16 second timeframe.

The SC4 view for this study was the preferred first and second-choice echo window. However, difficulties in this window resulted in an alternative selection and progression from the SC4 to the A4C or PSLA view. The more common second-line option is the PSLA, which is easier to acquire compared with the more challenging apical view optimally achieved with the patient in the left decubitus position (Aly et al., 2021). The rationale for the apical view as the second choice in this study is two-fold, with patients unable to be positioned due to the cardiac arrest and the placement of a CPR feedback ‘puck’ in the middle of the sternum, thus limiting access to the PSLA view.

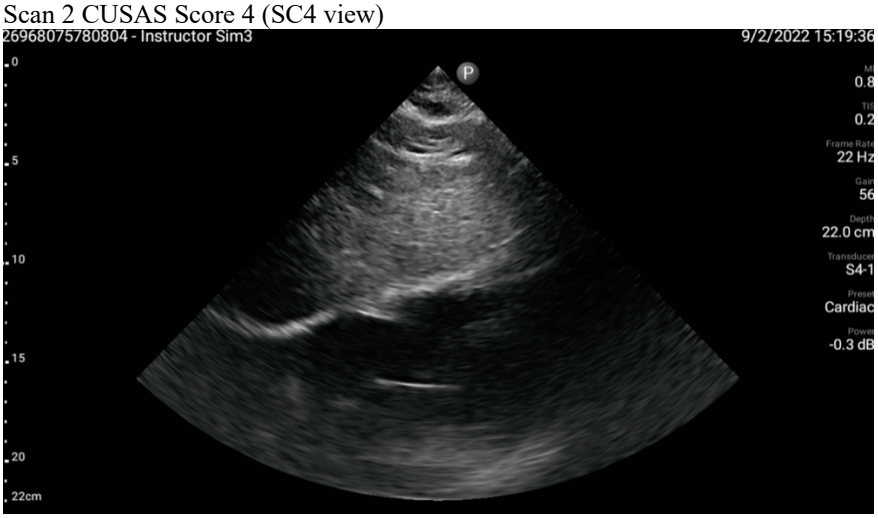
Figure 62

Assessor Scans Phase II Station Three (Group A)

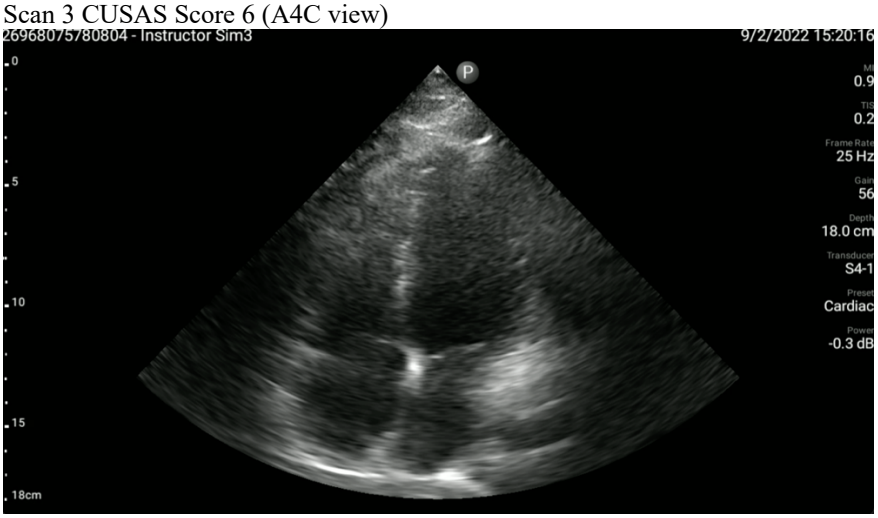
Scan 1 CUSAS Score 1 (SC4 view)



Scan 2 CUSAS Score 4 (SC4 view)



Scan 3 CUSAS Score 6 (A4C view)



Note. Images are still screen captures taken by the author from the best quality of the video loop.

The extended pulse check pauses can be linked to the simulation resuscitation team's difficulty and non-compliance, as they often delayed resuming compressions past the 10 second mark. This delay was exacerbated by ultrasound paramedics continuing to seek clearer views, inadvertently lengthening the HOT. Personal differences among participants further intensified this trend. This suggests that individual attributes or behaviours might have further exacerbated the prolonged HOT times, especially at this station. Such insights underscore the value of identifying paramedics with consistently extended HOTs. These individuals may significantly benefit from supplementary training to consistently hit the sub-10 second target.

While achieving the HOT within 10 seconds is critical for the current goal of maintaining CCF ratios, there are some inherent weaknesses of this approach. It is worth considering whether pulse checks in PEA cardiac arrest that are slightly longer than 10 seconds harm the resuscitation attempt. In this study, nearly 20% of HOT were 1-second over the 10 second pulse check pause. The importance of maintaining a high CCF of 60 to 80% in shockable rhythms is emphasised; however, Loza-Gomez et al. (2022) found that a high CCF (> 80%) led to a low CiT (13%), indicating that faster compression rates failed to achieve quality markers like adequate depth and recoil. Similarly, Vaillancourt et al. (2020) observed that a CCF of > 40% improved the chances of ROSC in non-shockable rhythms but didn't necessarily improve survival rates. Those patients in PEA with a CCF of < 40% had twice the odds of survival and received a reduced CCF but had the highest survival rate. This patient group may have suffered from pseudo-PEA and benefited more from therapies besides CPR. This insight provides a new perspective concerning the validity of the 10 second pulse check pause in non-shockable rhythms and the significance of CCF ratios specifically for PEA cardiac arrest.

Administering CPR to patients with an inherent heartbeat can be hazardous unless the compressions are aligned with the heart's natural rhythm. The risk of asynchronous CPR might lead to ineffective or counterproductive compressions. However, tailored vasopressor administration could improve resuscitation effectiveness. Supporting this, a study by Paradis et al. (2012) found that compressions timed with cardiac systole (ventricular ejection) led to higher coronary perfusion pressure (CPP). Likewise, Marill et al. (2020) show that switching from asynchronous to synchronous CPR increased the mean arterial pressure from 55 to 83 mmHg and the CCP from 32 to 60 mmHg. These studies suggest that asynchronous CPR may have a negative effect on pseudo-PEA. Ultrasound may offer a future solution for identifying pseudo-PEA and optimising CPR timing.

5.2.1 Summary of Research Question One

This research question aimed to establish if paramedics could obtain an ultrasound scan during the 10 second pulse check pause which was not achieved based on the 10 second time limit. The use of ultrasound during cardiac arrest resuscitations varies in effectiveness between studies. While some research shows over 90% of ultrasound scans are completed within the crucial 10 second window, the CAFE trial reports only 47.7%. A critical factor influencing these discrepancies may be the source of data. Studies drawing from real human subjects tend to provide more robust and clinically relevant insights than those relying on mannequin simulators, which lack the anatomical variation and realistic feedback of living tissues. The significance of CCF is debated, especially concerning non-shockable rhythms such as PEA. Synchronised CPR, where compressions align with the heart's rhythm, may enhance results, predominantly in pseudo-PEA situations. Tailoring training and protocols to the specific out-of-hospital setting appears key for effective resuscitation. Improved HOT

between phases II and III suggest familiarity and knowledge consolidation improves cardiac arrest ultrasound integration.

5.3 Research Question Two Discussion: Quality of Imaging

The study aimed to determine if 100% of paramedics could achieve a CUSAS score of ≥ 3 in at least 90% of simulated cardiac arrest echo attempts. The objective was not met, with paramedics scoring ≥ 3 in 83.7% (95% CI [78.4, 88.2]) of cases according to reviewer A and 77.7% (95% CI [71.9, 82.9]) according to reviewer B. Overall both reviewers agreed on a score of ≥ 3 in 73.9% (95% CI [67.8, 79.4]) of cases. The expectation of a 90% success rate appears overly optimistic, indicating that the current training may not be adequate for novice sonographers to reach the required competence level for clinical practice.

The CUSAS findings in this study are comparable with those reported by other investigators (Backlund et al., 2010; Chin et al., 2013; Kreiser et al., 2022; Reed et al., 2017). The study's CUSAS scoring reliability was moderate (k = 0.45, 95% CI [0.34, 0.58]) for simulation and echo skills but lower than Backlund et al. (2010), who reported substantial agreement (k = 0.6) but with fewer scans reviewed (n = 48) and 92% achieving a CUSAS ≥ 3.

This study broadly supports the findings of Rooney et al. (2016) who found that paramedics self-critiqued cardiac arrest images were deemed adequate in 89% (95% CI [67, 99]) of scans. This form of evaluation may not be as impartial or as rigorous as an assessment made by external experts. Also, their study was smaller, with 19 participants, and only the PSLA and SC4 views were used. The CAFE study employed expert reviewers, enhancing validity of results, and confirming overall image quality.

The stand-alone echo skills station showed a non-statistical decline in CUSAS scores in the echo skills station compared to simulation, the overlapping confidence intervals highlight the complex challenges faced in real-world clinical scenarios. The findings underscore the importance of understanding and adapting to the complexities of cardiac imaging during live patient care, where factors like patient body type and clinical conditions can impact image quality and diagnostic accuracy.

In this study, a clinically relevant observation was made between phase II and phase III scans. In phase II, scans conducted within the 10 second pulse check pause showed an approximate 10% difference in achieving a CUSAS score of ≥ 3. Notably in phase II, there was a tendency for quicker scans to yield lower image quality, likely attributed to inexperience. In contrast, during phase III, about 10% more scans achieving a CUSAS score of ≥ 3 was within the 10 second pulse check pause. This may be due to improved familiarity and the addition of a second simulation that enhanced practical skills. In practical terms, these findings underscore the importance of experience and targeted training (like simulations) in improving the quality of scans, especially when time is limited. They highlight the potential challenges for those new to the technique (as seen in phase II) and the benefits of continued practice and training (as evidenced by the improvements in phase III).

Understanding the substantial differences between simulation and echo skills stations is crucial. Echo skills stations necessitated that participants gather one image of all three views and identify anatomical structures within a 5-minute timeframe. Conversely, simulations primarily involved SC4 views acquired within 10 seconds. Collecting data on all three echo views was to assess whether paramedics could obtain high-quality views in all echo windows and effectively describe key anatomical structures to interpret the CAFE exam.

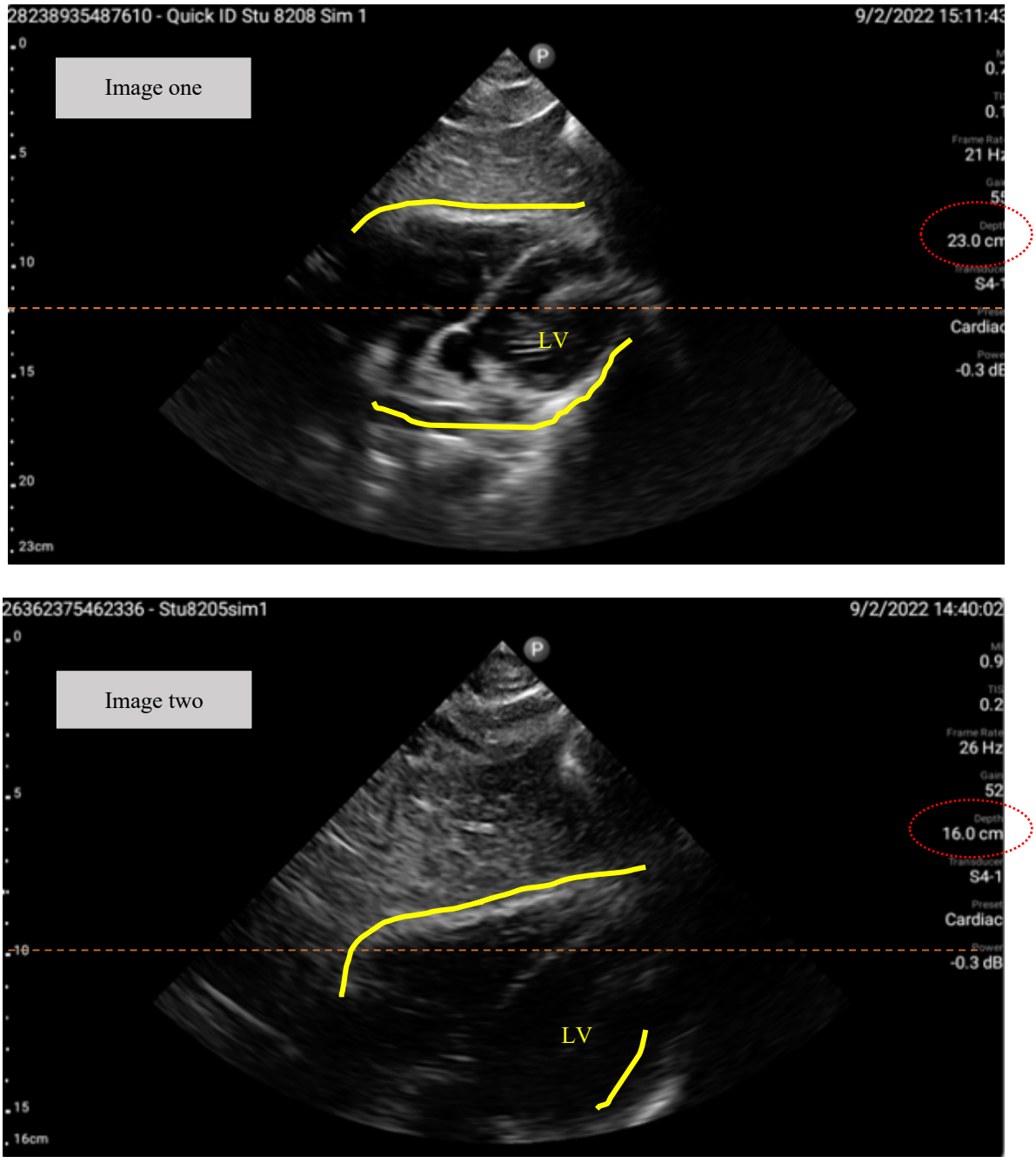
As previously discussed, high-quality images with a CUSAS score of ≥ 3 are required for accurate clinical judgment and evaluation during cardiac arrest. In this study, paramedics were taught to optimise their images using the settings of depth (ultrasound penetration), gain (image brightness) and transducer axis orientation (target object). Since image depth is central in determining the examination window, the depth should always be greater than the structure of interest (Zander et al., 2020). For optimal image quality in the SC4 view, participants were encouraged to pre-set their ultrasound image depth to 23 cm before scanning to optimise image quality. The study found that image depths of 23 and 25 cm were selected in 45.2% of scans, but 27.3% selected 16 cm as the most frequently chosen depth over repeated measures. Image depth is crucial when performing ultrasound as the focal zone provides image clarity and the visibility of specific anatomical structures in the scan view.

The FEELS trial provided recommendations on depth selection, proposing that for an enhanced view, the ultrasound depth should be set at a minimum of 15 cm (Breitkreutz et al., 2009). For the CAFE study, the minimum depth selected by one participant was 14 cm, demonstrating that all but one image depth was set within the FEELS trial standard. Comparing image depth with the CUSAS score, depths 16, 19, 23, and 25 cm were correlated with a significant proportion of adequate images (≥ 3). However, there was no significant correlation between CUSAS score and image depth (p = 0.357). The characteristics of the healthy volunteer cohort may explain this result. Given that these models were slender and lacked lung or cardiac disease, the selection of imaging depth became less critical during scanning. Consequently, this cohort may not fully represent the general cardiac arrest population, where higher body mass index and the presence of lung and cardiac disease are more common. In general, if the image setting is too shallow or deep, the image quality is reduced, and relevant structures are not seen. The paramedic can adjust image depth using depth sliders on the ultrasound device screen. For example, Figure 63 visually compares two

scans taken by two study participants from simulation station one, group A. Image one is set at a depth of 23 cm and scored a CUSAS of 4 and 6 from reviewers A and B. The LV is positioned within this image's focal zone, improving resolution. In the second image, the focal zone is set at a depth of 16 cm, marking the boundary between the liver and pericardium. Both reviewers gave this image a CUSAS rating of 4. Even though the images exhibit varying depths, they adequately present information to evaluate LV function and detect pericardial effusion in the dependent area between the liver and the right ventricle.

Figure 63

Depth Selection Comparison



Note. Ultrasound scans from simulation station one group A. LV = Left Ventricle, orange dotted line = ultrasound focal zone, red circle = depth selected, yellow outline = pericardium outline.

Given that the CAFE exam looked for evidence of pericardial effusion, the correct depth setting of an image would be helpful. The most common location for pericardial fluid collection is between the liver and the right ventricle. Cardiac tamponade can be caused by an effusion that hinders venous return and, thus, the heart's filling. Sonographic signs of tamponade physiology are unique to the right side of the heart. Although pericardial effusion in the context of PEA cardiac arrest is uncommon, it is a potentially reversible cause. To provide clinical context, a large (n = 953) prospective multi-centre investigation by Gaspari et al. (2016) identified 34 (4.2%) of 793 patients had sonographic pericardial effusions during cardiac arrest resuscitation, with 13 requiring pericardiocentesis. Remarkably, two patients who underwent the pericardiocentesis procedure demonstrated successful outcomes, surviving to hospital discharge. Whilst the frequency of known pericardial effusion is low, inclusion within cardiac arrest ultrasound protocols should always be considered.

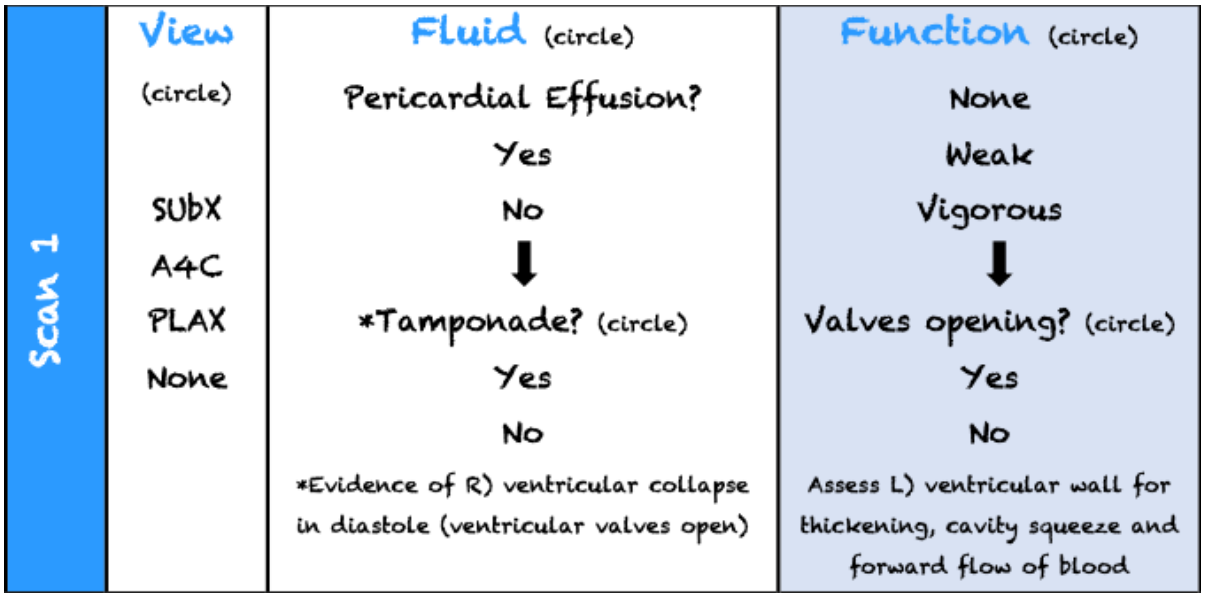
Smaller ambulance services such as Wellington Free Ambulance grant special authority for flight paramedics beyond the National Clinical Practice Guidelines to perform a pericardiocentesis procedure for suspected cardiac tamponade in traumatic cardiac arrest. The current pericardiocentesis procedure involves using anatomical landmarks and is a blind procedure to attempt aspiration of the effusion. Ultrasound application would facilitate the detection of effusions and enable direct visualisation of the pericardium. Ultrasound is highly sensitive and specific for diagnosing cardiac tamponade but depends on the operator's skill (Alerhand & Carter, 2019). Ultrasound needle guidance facilitates real-time visualisation of the procedure, ensuring precise placement and reducing injury to adjacent structures (Blanco et al., 2022). The identification of a pericardial effusion by ultrasound, while not integrated into current New Zealand paramedic or flight paramedic practice, is an essential component of the CAFE fluid assessment. The inclusion underscores the significance of identifying and potentially treating tamponade, a potentially reversible cause of PEA cardiac arrest. From a

risk stratification perspective, there are generally no contraindications to using ultrasound unless performing the procedure is deemed unsafe. However, considerations of conditions such as aortic dissection and ventricular rupture in settings without immediate surgical facilities may render diagnosis futile (Blanco et al., 2022). Both complications will only be identified if an ultrasound is performed. Furthermore, ultrasound offers a safer approach for drainage procedures, mitigating risks associated with invasive interventions.

Image optimisation and its impact on the CUSAS score have been the main topics of this section thus far. Examining the CAFE exam report form, which was created especially for this study, is also crucial. Although phases I and II and the refresher module included instruction on using the CAFE form, there is still room for improvement. Chin et al. (2013) developed a flow chart to evaluate ultrasound in cardiac arrest. The use of descriptive prompts such as “Is there an anechoic space between the heart and the pericardial line?” (p.144) is less complex than the evaluation of tamponade physiology used in the CAFE exam as shown in Figure 64. The CAFE exam tamponade description included “Evidence of right ventricular collapse in diastole (ventricular valves open)” as a written prompt.

Figure 64

CAFE Exam Report Form

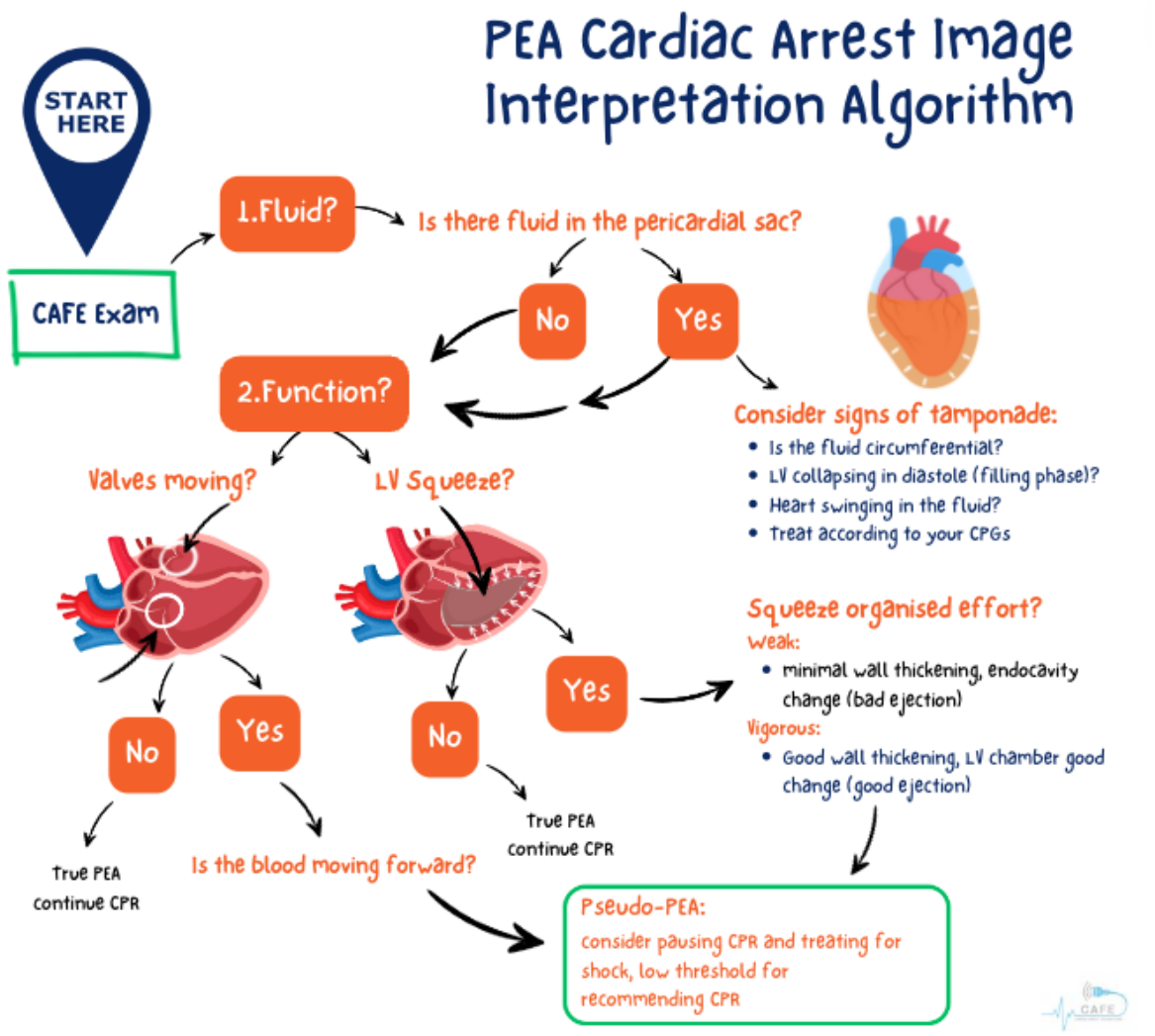


Note. Screen capture provided by the author.

In the future, the CAFE exam fluid and function check form will be updated to avoid confusion regarding tamponade errors in the absence of pericardial effusion. Additionally, the function assessment will prioritize evaluating valvular movement first, based on this study's findings showing improved accuracy in determining pseudo-PEA. A proposed algorithm for interpreting results is shown in Figure 65.

Figure 65

PEA Cardiac Arrest Image Interpretation Algorithm



Note. This algorithm is a suggestion for future development of ultrasound integration into PEA cardiac arrest.

5.3.1 Summary of Research Question Two

The study investigates the ability of paramedics to achieve a CUSAS score of ≥ 3, a benchmark for adequate image quality. Although promising, the results fall short of the targeted 90% efficacy, with 77.9% achieving the desired score. Factors such as time constraints and the complexity of high-fidelity clinical scenarios, including challenges related

to patient scan difficulty, may contribute to lower scores. The study also discusses the importance of image depth settings, revealing that while there is no significant correlation between depth and CUSAS score, optimal depth settings are essential for clear images. Additionally, user experience plays a role in achieving optimal image quality. This information aligns with prior research and contributes uniquely to best practices in echo imaging.

5.4 Research Question Three Discussion: Interpretation

The third research question evaluated if 100% of paramedics could identify the presence or absence of pericardial effusion, pseudo-PEA, true PEA, left ventricular contraction and valvular movement for at least 90% of cases. This evaluation involved analysing the CAFE exam. The pathological scan interpretation findings showed that paramedics were 91.9% accurate meeting the research aim; however, the confidence interval (95% CI [88.5, 94.5]) suggests a small risk of true success falling slightly below the desired 90%. While the findings are promising, continued development of the CAFE exam and interpretation may be needed to ensure consistent achievement of this target.

The study found high accuracy in participants' ability to correctly rule out pericardial effusion at 91.7% (95% CI [87.5, 94.9]). However, errors increased from the first to the third scan, potentially due to diminishing clarity in anatomical structures and less familiarity with complex cardiac images. This finding highlights the difficulties posed by more complex or challenging images in accurately identifying the presence or absence of pericardial effusion.

Examining tamponade physiology there is a slight decline in the accuracy of image interpretation for ruling out tamponade physiology from 97.7% (95% CI [91.9,99.7]) in phase

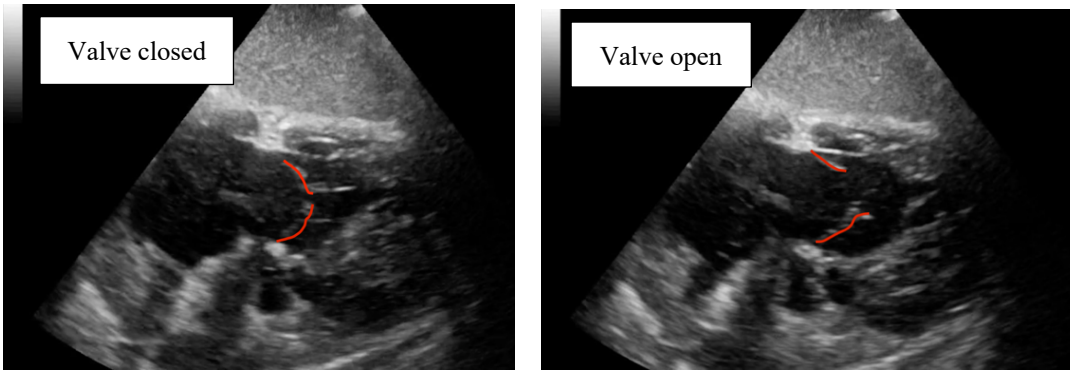
II to 94.8%, 95% CI [90.1, 97.7]) in phase III. However, these results show consistent performance meeting the target of 90%.

The accuracy of interpreting the left ventricular squeeze was relatively low, with 74.7% (95% CI [64.2, 83.4]) accuracy in phase II with a slight decline in phase III (73%, 95% CI [65.4,79.8]). Overall accuracy was 73.6% (95% CI [67.6, 79.0]). In contrast, valvular opening was consistently high, with 100% of cases in phase II and 99.3% (95% CI [96.4, 99.9]) in phase III, demonstrating a high level of accuracy for valvular opening.

Diagnostic accuracy in the current study was similar to previously reported findings (Kreiser et al., 2022; Price, Uddin, et al., 2010) where left ventricular squeeze interpretation proved more challenging. Notably, errors were more frequent when assessing vigorous left ventricular squeeze, making up 51.3% of mistakes, whereas only 5.8% were in cases with no visible squeeze. The valvular opening assessment showed high accuracy, suggesting it may be a more reliable metric for novice ultrasound users. An intriguing educational insight emerged regarding the assumed link between left ventricular function and valvular movement. Participants often incorrectly interpreted valvular opening based on observations of ventricular squeeze or the lack thereof. Figure 66 illustrates this point with the second image in the SC4 scan series, highlighting the degree of valvular opening of the tricuspid valve, suggestive of forward flow in association with a weak squeeze.

Figure 66

Right Atrioventricular (Tricuspid) Valve Activity



Note. Red outline highlighting the tricuspid valve.

This finding shows the importance of understanding the clinical correlation between valvular movement and ventricular squeeze. In cases where the mitral valve is not visible during the ultrasound, participants were guided to evaluate the tricuspid valve or vice versa. This protocol ensured that some valuable cardiac information was captured, even if the left atrioventricular valve itself could not be assessed at the time. This approach highlighted the flexibility required in real-world clinical settings and underscored the importance of training in diverse conditions to enhance diagnostic accuracy. Echo interpretation during cardiac arrest is challenging, even a slight movement of the probe or ventilation of the patient can be mistaken for cardiac activity when there is none.

In the CAFE study, each participant had a total of 90 minutes of hands-on scanning experience across ten scans and five stations. This demonstrated a quick learning curve for paramedics in acquiring practical ultrasound skills. The condensed training in the CAFE study was practical and achievable within the study's timeframe and resources. However, the importance of comprehensive training programs, as outlined by Blehar et al. (2015) suggest a

plateau of essential echocardiography learning after approximately 30 scans. The educational approach used aligns with existing guidelines and suggests that the training model is appropriate across three dimensions: knowledge, image acquisition, and interpretation (Price, Uddin, et al., 2010). Notably, the Australasian Society for Ultrasound in Medicine (ASUM) guidelines recommend 6 hours of instruction, including four practical hours, 25 scans, and interpretation of 50 scans with defined pathology (Australasian Society for Ultrasound in Medicine, 2021b). This framework underscores the importance of structured and comprehensive training and proficiency beyond research project constraints.

In contrast, this study provided participants with a brief 90-minute training with ten scanning opportunities each. Despite this abbreviated training period, paramedics showcased a commendable aptitude for the skills of ultrasound. This suggests that while enhanced outcomes might be achievable with extended scanning opportunities, as recommended by ASUM, even brief focused training sessions can effectively impart the essential skills of ultrasound in a focused setting. The results underscore the potential merits of a streamlined educational approach even though a more prolonged educational pathway would be the ideal.

The skills for image interpretation traditionally involve face-to-face learning and developing skills over time (Blehar et al., 2015). In the CAFE study, the ‘flipped classroom’ was used allowing the learner to participate in the modules during their own time, managing shift work requirements and reducing the burden of attendance in the classroom. All 30 participants participated and completed the phase I eLearning module. Module content included videos, infographics, and written text to demonstrate ultrasound device use, sonographic anatomy, cardiac arrest sonographic physiology and image acquisition skills. A wide range of presentation media was used to cater for varied learning styles.

In terms of knowledge and interpretation accuracy, it appears that performance during the first simulation scan was impacted by a lack of experience and unfamiliarity with the equipment. This suggests that while participants may have quickly acquired basic skills, the initial learning curve did affect the accuracy of early scan interpretations. As paramedics become more comfortable with the technology and procedure, we would expect to see improvements in both knowledge and interpretation accuracy. We also rotated participants among five different scanning stations to diversify their experience by scanning different healthy volunteers.

In phase II, participants received stepwise face-to-face education, starting with equipment familiarity, progressing to echo view acquisition, and culminating in cardiac arrest integration. With a favourable 1:3 instructor-participant ratio, they rotated through five scanning stations, ensuring an enriching educational experience that maintained engagement and resonated with contemporary ultrasound teaching approaches (Landry et al., 2017). Despite these educational efforts, phase III showed a slight dip in interpretation accuracy to 89%, potentially signalling a decline in knowledge proficiency over time. This is an important consideration for real-world clinical practice where sporadic use, or a lack of ongoing training could affect performance. To improve competence, various strategies such as continued education, routine practice sessions, refresher courses, and simulation-based training could be offered or encouraged.

Expanding the use of ultrasound in out-of-hospital settings, particularly for cardiac arrest scenarios, remains a challenge due to the current lack of availability of ultrasound devices in road-based ambulances. However, there are some promising developments with a few paramedics holding credentials for using ultrasound in trauma and vascular access, which is a significant step forward. To further this progress, the author is working with the

Australasian Society for Ultrasound in Medicine developing a specific Certificate in Prehospital Performed Ultrasound (CPPU) which is discussed further in the section titled ASUM Annual Congress CPPU Abstract.

5.4.1 Summary of Research Question Three

The research question aimed to determine if paramedics could accurately identify various cardiac conditions through ultrasound, targeting a 90% accuracy rate. Utilizing a brief 90-minute training program, paramedics demonstrated varying levels of proficiency: modest accuracy in interpreting pericardial effusion, the lowest accuracy in left ventricular squeeze, and the highest consistency in identifying tamponade and valvular opening. These results support the study's educational approach and suggest that even with limited training, paramedics can quickly acquire essential skills for use in cardiac arrest ultrasound. However, the variable findings highlight target areas for improvement.

5.5 Research Question Four Discussion: Underpinning Knowledge

The fourth objective addressed the research question of whether 100% of paramedics could achieve an individual pass mark of ≥ 80% in the knowledge quiz and accurately identify the presence of cardiac tamponade. Multiple choice questions were conducted to assess participants' knowledge and understanding throughout the study. The quiz consisted of multiple-choice questions strategically developed to assess participants' knowledge and understanding across key study areas, including echo view identification, sonographic anatomy, fluid and function determination, and identification of PEA and cardiac tamponade.

Despite not meeting this target with significance just above threshold ($p = 0.051$), the observed increase in pass rates from 58.6% (95% CI [40.7, 76.5]) to 76.9%, 95% CI [60.7, 93.1]) suggests improvement. The wide confidence intervals indicate varied participant

performance, suggesting that education may be effective for many but insufficient for all. The need for tailored education and education support was highlighted, with six participants showing reduced performance in phase III.

The study did not explicitly evaluate skill decay with four weeks between phases II and III. Nevertheless, it remains crucial to consider this aspect when assessing the longevity of knowledge derived from educational interventions. The refresher module completed by 24 participants may have contributed to this improvement. Of note the study could not conclusively determine if participants sourced ultrasound education information outside of the course content. The effect size was calculated showing a medium effect with practical significance for general improvement in knowledge retention. Such findings bolster the argument for periodic training sessions in reinforcing and enhancing knowledge.

One notable limitation was the use of identical MCQs across both phases. While this simplifies comparisons, it raises questions about whether the observed score improvements reflect genuine understanding or merely familiarity with the test questions. Despite a 1-month gap between phases which may have minimized answer recall, this methodological choice does not fully address the issue of test familiarity. Participants were unaware of question duplication between phases, highlighting a consideration for future quiz construction. Additionally, Phase II's longer duration (5.5 hours) may have caused fatigue, whereas Phase III, consisting solely of assessments, likely reduced fatigue and potentially improved cognition.

Additionally, participants only received their overall test scores and were not given individualised feedback or the opportunity for review, which could limit the educational value of the testing experience. Participants were allowed continued access to phase I eLearning modules and a 30-minute refresher module between phases II and III. Student

centred learning and the pedagogy of the flipped classroom relies on the student's individual interest, time flexibility and autonomy (Koh, 2019). Modern educational practices frequently facilitate free and open access to learning resources, aligning with the increasing trend of offering materials through online platforms or proprietary educational systems. Therefore, while the study shows promise in its educational outcomes, these limitations and design choices should be considered when interpreting the results.

While reviewing individual quiz questions, it became evident that there were certain areas where participants performed consistently well and others that posed challenges. Specifically, in question one, echo view selection shows slightly higher accuracy in phase II than in phase III, which could be explained by loss of knowledge over time. Accuracy in question two was conversely high, with correct labelling of structures in the SC4 view suggesting participants were familiar with this view as part of the CAFE exam emphasis. Question three exhibited lower accuracy rates in both phases, suggesting additional difficulty with question design and challenges with labelling and matching colours and numbers with individual anatomy in the PSLA view. Question 10 presented a pericardial effusion image and patient case history. The accuracy between both phases was similar 75.8% (95% CI 56.4,89.7]) and 80.7% (95% CI [60.6, 93.4]) suggesting that participants had a good understanding of the visual appearance of pericardial effusion and tamponade physiology. However, in question nine, participants were less able to articulate tamponade physiology 34.3% (95% CI [17.9, 54.3]) in phase II and 53.8% (95% CI [33.3, 73.4]) in phase III with limitations identified by how points were awarded. The education provided for tamponade physiology was emphasised in the 30-minute refresher module and may explain the increase in accuracy for this question in phase III.

Comparing the CAFE study with the results from the literature is challenging due to the varied methods, educational content, and testing across studies. A study by Bhat et al. (2015) employed pre and post-education MCQs, specifically examining test scores for pericardial effusion. The scores before and after were 57.9% and 84.6%, not dissimilar to the CAFE study results post-education. The PAUSE pilot trial demonstrated excellent pathology identification of 91% after 2 hours of training. Interestingly, cardiac standstill recognition within their findings included three misidentifications of pericardial effusion (Chin et al., 2013). This finding resonates with the CAFE results, suggesting that as the cardiac arrest progresses and the heart becomes less responsive, the identification of the pericardium becomes more challenging.

5.5.1 Summary of Research Question Four

Based on the results obtained, it can be concluded that the focused and condensed education provided did not meet the objective of achieving a pass rate of ≥ 80%. The participants' performance in the knowledge quizzes indicated that the educational intervention was adequate for some participants but not all. The identification of knowledge gaps among participants suggests that the educational intervention was effective in pinpointing areas where additional training or support is needed. Recognising knowledge gaps is valuable as it enables educators to focus future interventions and address specific areas of weakness, thereby enhancing the overall educational experience for the learners. Of importance is the transference of this education into the real-world setting. Although participants demonstrated knowledge and identification of good-quality images reviewed in an exam setting, translation into clinical practice will present additional challenges.

5.6 Incidental Findings Discussion

Image acquisition and Hands-off time. The data indicates that frequency of achieving a CUSAS score of ≥ 3 within 10 seconds is challenging for novice ultrasound users with minimal experience. However, phase III showed an approximate 20% improvement in achieving this goal suggesting room for improvement. The increase in HOT was statistically illustrated by comparing the duration of each simulation scan using binary logistic regression. The data indicates that the ease of image capture differs among patients, consequently influencing the time required for image acquisition. To address these variations, ultrasound training for paramedics should incorporate alternative imaging perspectives like the A4C and PSLA, ensuring more effective image capture in diverse scenarios. However, these alternative views also come with their own challenges; they are harder to acquire and could potentially disrupt chest compressions, thus lengthening the HOT.

5.7 Strengths and Limitations

Structured Simulated Environment. One of the significant strengths of the CAFE trial was the use of simulation as a primary tool. The simulation environment ensured participants could operate safely and controlled, allowing specific variables to be isolated and tested without extraneous distractions or confounding elements. Such an environment enabled more precise data collection, especially when emulating the unpredictable nature of real-life working settings.

Consistency in Equipment. Adopting the Philips® Lumify ultrasound device across all study phases offered uniformity improving the strength of measurement consistency and reduction of measurement bias. This consistency facilitated participants to develop familiarity with the ultrasound device, which, over time, had the potential to enhance their proficiency.

Data Collection. Even with the limited sample size, the study was tailored so that the applied statistical tests effectively detected associations or effects. The limited sample size may result in generalized conclusions. Pandemic related logistical difficulties and additional stress on participants' may have impacted the engagement and consistency of findings.

Flexibility in Adverse Conditions. The adaptability of the study, especially during the challenges presented by the SARS-CoV-2 pandemic, reflects resilience. Conditions were adapted to try and ensure that the research progressed with minimal loss of data.

Attention to Feedback and Continuous Improvement. Whilst there were challenges associated with the equipment and simulation, these have already been acknowledged. Feedback from participants and instructors was noted, implying an openness to refine and optimise processes and tools based on real-world input.

Commitment to the Participant. Despite the potential risks associated with the familiar relationships between participants and researchers, the study structure empowered the participants. By keeping the author blinded to participant identification and ensuring they weren't directly involved in assessments, the study aimed to minimize bias and maintain the objectivity of its findings.

Methods. This study experienced significant challenges, particularly due to the recruitment of actively working paramedics amidst a pandemic. The methodology required participants to attend phases II and III during their days off, offering minimal compensation. This design could introduce selection bias, as paramedics willing to participate may differ in characteristics, attitudes, or behaviours compared to those who declined. However, the groups were homogeneous with no prior exposure to ultrasound and assessments were identical. Additionally, the inherent nature of shift work in the paramedic field could

influence study outcomes, as factors like fatigue and motivation could affect performance. The study sample size was capped at 30 participants due to constraints such as venue capacity, faculty staff and healthy volunteers' availability. The study design and statistical tests could detect a significant effect or association despite the smaller sample size. However, caution should be exercised when interpreting the results, as the sample size might limit the generalizability of the findings to the wider paramedic population. Staff shortages and health-related absences among volunteers posed challenges by preventing participation and potentially affecting the consistency of the results and conclusions. However, this variable improved the variety of healthy volunteers scanned, providing further insight into characteristics affecting performance. Unavoidably there was some missing data for CUSAS image review by raters A and B and study participant non-attendance. Adjustments were made for the image review data set where absent data was removed pairwise.

The gender variance analysis was insignificant; however, the potential lower representation of females may introduce bias and limit the generalisability of findings. Gender-specific effects were not investigated due to a small sample size reducing any potential impact on study outcomes. The use of anonymity has limited the potential to explore gender-related variables and is worth considering in future studies.

Simulation. The timing and accuracy of measurements made simulation an effective tool to evaluate the time-sensitive nature of the 10 second pulse check pause and evaluate technical skill. The operational working environment yields stressors and insights not accounted for in the simulation. Testing reliability is limited in transfer to the real setting. Two assessors were recruited on short notice for group B, reducing lead-in time. Assessors were sent a link to a video to improve the standardization of teaching and assessments. One assessor suggested installing a prompt card for simulations for the last group to enter phase

III. In hindsight, assigning each healthy volunteer to a scanning station for both groups A and B would facilitate in-depth comparison of difficult scans and identify characteristics associated with the 'patient' and participant. However, pandemic illness impacted the availability of models.

Equipment. The Philips® Lumify ultrasound device was used across all study phases, providing continuity of use and familiarity. In some cases, the ultrasound gel hindered touch screen sensitivity, rendering the participant unable to capture an image, and this was observed as a feature of prolonged pulse check pauses. Other observed problems were a combination of user error, soiled fingers and proximity of the record and freeze buttons on the device. This caused confusion and delays in some simulations, leading to accidental image freezing instead of recording. The 8 second video loop, intended to instil urgency, led to extended pauses beyond 10 seconds with delayed activation of the video loop button. An ultrasound CPR mode with a standardized approach and simplification of the interface may address these challenges. The study also highlights the need for expert reviewers to enhance validity and address technological aspects, such as the choice of ultrasound devices, that can influence image quality.

Online Knowledge Quiz. Unpredictable internet speed and connection stability hindered ultrasound image loading and question progression. Improved conditions could include pre-downloading content, offline mode, or paper-based tests. The use of the same set of questions presented and re-presented in the online knowledge quiz may raise concerns about assessment validity and rigor. Education theory suggests that constructing a randomized bank of questions would enhance assessment validity by reducing predictability and ensuring a more comprehensive coverage of learning outcomes (Krzic & Brown, 2022).

The participants' computer literacy also posed barriers, with some struggling with touchpad or laptop technology.

Designing assessments that accommodate participants' technical proficiency is critical for ensuring fair evaluation. While the MCQs were appropriately pitched, relying solely on overall correctness for grading may be limiting. Incorporating a randomized bank of quiz questions would not only reduce the repetitive nature of the quiz but also enhance assessment validity by providing a more robust and varied evaluation of participant knowledge and understanding.

5.8 Practical Implications and Recommendations for Future Research

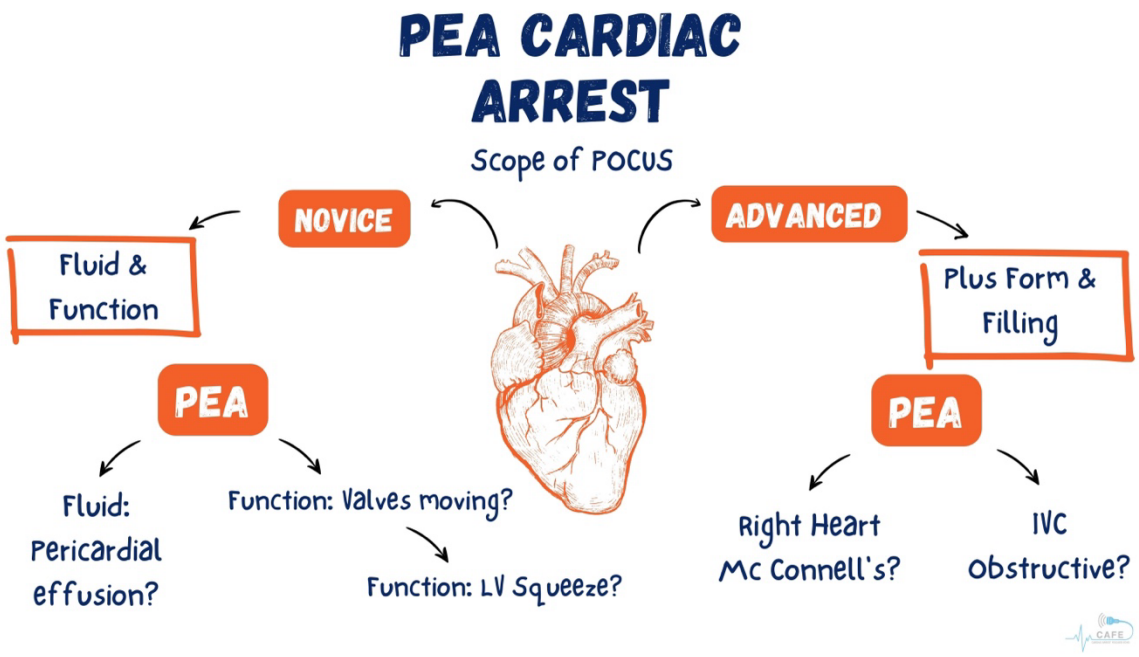
The growing body of evidence and confidence with recent out-of-hospital trials supports the incorporation of ultrasound into cardiac arrest management. However, barriers to implementation remain - including ultrasound device cost, clinical governance and oversight, and the development of ultrasound in general paramedic practice. Once ultrasound is woven into everyday paramedic practice to inform care and improve patient outcomes, cardiac arrest ultrasound may become less contentious.

Ultrasound use in PEA cardiac arrest. Ultrasound is used to answer focused clinical questions to identify reversible causes of cardiac arrest. The spectrum of ultrasound competency determines the validity of ultrasound within cardiac arrest care. A novice user is best placed to answer binary questions such as those used in the CAFE exam assessing pericardial effusion and the function of the left ventricle. In contrast, the advanced or experienced user may ask in-depth questions assessing the right heart form and fluid status of the inferior vena cava. The commencement of competency-based use of ultrasound in PEA cardiac arrest necessitates a framework identifying the focus of ultrasound use across various

domains of clinical practice. Figure 67 introduces the concept of a 'Novice' and 'Advanced' scope of POCUS use based on the Sonography in Hypotension and Cardiac Arrest (SHoC) protocol (Atkinson et al., 2017).

Figure 67

PEA Cardiac Arrest POCUS Competency



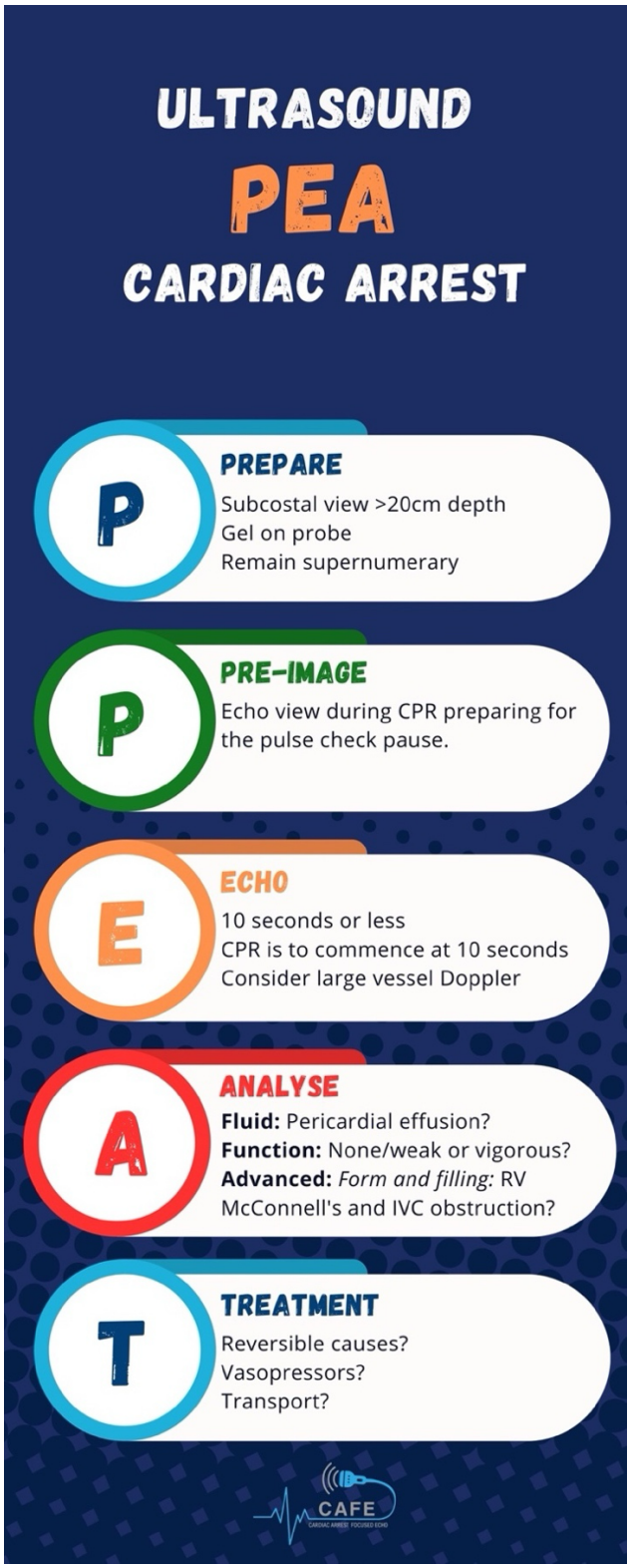
Note. Image created by the author using Canva.com (paid version).

P-PEAT Algorithm. The success of algorithms such as the chain of survival proves the efficiency of decision-making around cardiac arrest care. Implementing an algorithm specifically for ultrasound use in PEA cardiac arrest supports consistency and provides a standard of care. Informed by the CAFE research and other investigations, the author developed an algorithm to guide practice. The proposed PEA cardiac arrest ultrasound

algorithm encapsulated in the mnemonic ‘P-PEAT’ stands for Prepare, Pre-image, Echo, Analyse, and Treatment, as illustrated in Figure 68.

Figure 68

P-PEAT Cardiac Arrest Algorithm



Note. Image created by the author using Canva.com (paid version).

The P-PEAT algorithm is simple, focusing on performing the basics well. The ultrasound paramedic should ‘Prepare’ the equipment with a pre-set depth of > 20 cm, probe pre-gelled, and remain supernumerary to the cardiac arrest. Remaining supernumerary removes interruption to the advanced cardiovascular life support care delivered by the resuscitation team. The use of ‘Pre-imaging’ allows the ultrasound paramedic to position the probe in the SC4 window during the CPR cycle, further reducing HOT. The ‘Echo’ is the acquisition of the ultrasound during the pulse check pause with emphasis on brevity. When considering large vessels, Doppler[7] measurements are helpful, particularly in the austere out-of-hospital care environment where an echo window may not be optimal or accessible. The option of Doppler waveform detection is beyond this study but should be considered a secondary investigation. A study conducted by Cohen et al. (2022) suggests that Doppler ultrasound demonstrated superior accuracy for pulse detection compared to manual pulse palpation (95.3% vs. 54.0%, $p = < 0.001$). When a Doppler pulse is detected, a pause in CPR provides an opportunity for an echo scan. This approach could be a lateral move towards a more adaptive algorithm in such circumstances. However, there are limitations to using Doppler ultrasound, including user experience, knowledge of Doppler shift, and the handheld device’s functionality, as not all devices have Doppler capability. A visual evaluation of pulsation in the vessel could be used; however, this technique needs further evaluation to determine if pulsation is visible in a low-flow shocked patient.

The ‘A’ letter in the P-PEAT algorithm stands for ‘Advanced’. The ‘Advanced’ section describes the evaluation of the right heart, looking for signs of PE, specifically Mc Connell’s sign[8] and the IVC for evidence of obstructive shock. The addition of ‘Advanced’

[7] Doppler ultrasound measures frequency shifts to estimate blood flow velocity in a vessel.

[8] McConnells sign is a right ventricular regional pattern of acute heart strain and right ventruicular akinesis and apical sparing observed in pateints with pulmonary embolism.

allows the P-PEAT algorithm to be used by all levels of practitioners. While assessing the right heart and inferior vena cava is beyond the scope of the CAFE exam, it becomes relevant when paramedics develop experience and proficiency in echo allowing skill and knowledge progression. The next step in the P-PEAT algorithm is to 'Analyse' the scan using the fluid and function assessment, looking for reversible causes of PEA, pseudo-PEA or a low-flow shocked heart. The final step is to consider 'Treatment' and transport options. The overall aim of the P-PEAT algorithm is to provide consistency of scanning in PEA cardiac arrest and to normalise the process.

5.9 Practice Change

The CAFE research opportunity has positioned the author to influence practice change in out-of-hospital ultrasound. The author was poised to lead and develop the postgraduate paramedic ultrasound course at AUT. At present this course is offered as a standalone paper or as part of a postgraduate certificate, diploma, or masters. The ultrasound course is 150 hours of learning (15 points) over 12 weeks with online theoretical learning using various interactive media. Enrolled students attend a 2-day comprehensive block course led and delivered by the author and supported by ASUM credentialled doctors and sonographers. Learning modules consider low- and high-acuity patients in out-of-hospital settings, as shown in Figure 69. The author has designed and facilitated this course intending to provide an appropriate education opportunity for paramedics to achieve competency in out-of-hospital ultrasound techniques.

Figure 69

Auckland University of Technology Postgraduate Ultrasound Course

Week 1	Ultrasound Physics and Safety
Week 2	Ultrasound Probes and Artifacts of Ultrasound
Week 3	Respiratory Ultrasound
Week 4	Echocardiography 1
Week 5	Echocardiography 2
Week 6	Abdominal Ultrasound 1
Week 7	Abdominal Ultrasound 2
Week 8	Trauma and Undifferentiated Shock
Week 9	Procedural Guided Ultrasound
Week 10	Community Care and Cardiac Arrest Integration
Week 11	Critical Care Paramedic Ultrasound Application Extensions
Week 12	Bringing it all together – Consolidation of ultrasound learning

At the time of writing this thesis course work required students to complete two essays within 12 weeks. The first is on the physics of ultrasound, and the second is on the application of ultrasound out-of-hospital using a case-based presentation about their clinical practice. Students must also attend three online lectures, from a total of six. This course creates a pathway for out-of-hospital clinicians to learn ultrasound in New Zealand with the support of ASUM.

The existing ASUM Certificate in Allied Health Performed Ultrasound (CAHPU) is a credentialing mechanism for various allied health professionals, including paramedics. However, it's important to note that whilst this pathway exists there is limited scope of practice to enable practice of ultrasound skills. The CAHPU certificate focuses primarily on ultrasound use within hospital settings. Of the 11 modules offered, only three are appropriate for out-of-hospital application. These modules include eFAST, vascular access and basic early pregnancy. The addition of abdominal aortic aneurysm (AAA), basic soft tissue examination, proximal deep vein thrombosis, renal hydronephrosis and calculi, focused echo

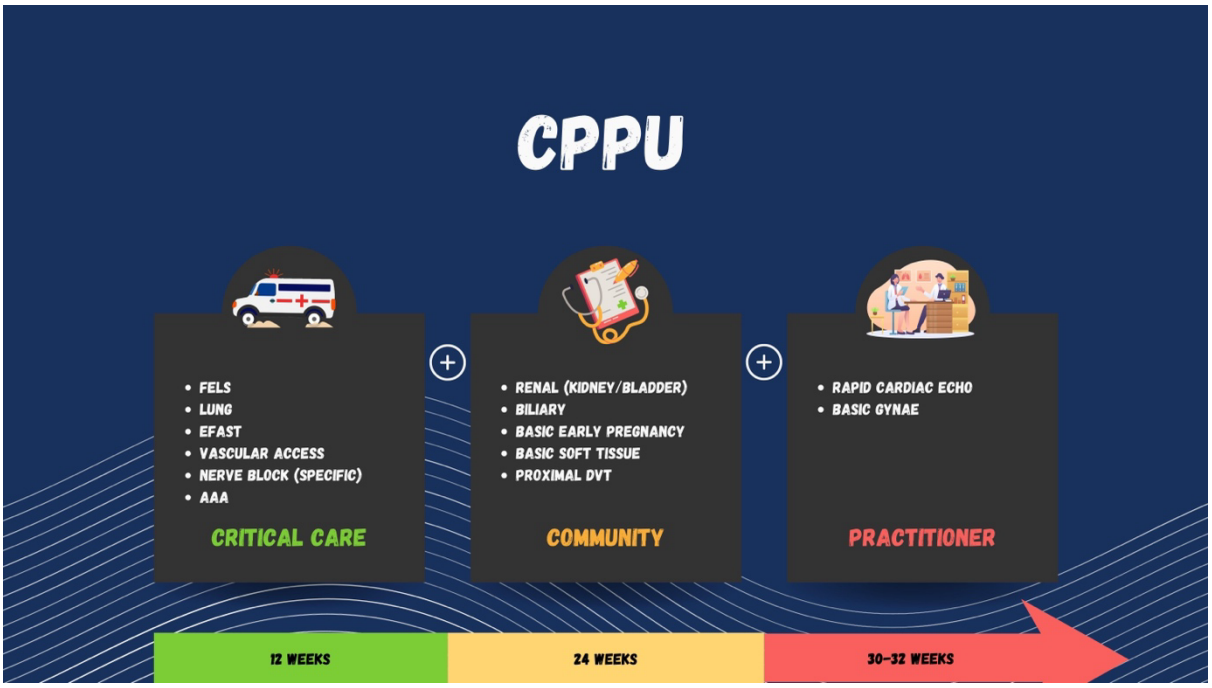
in life support (FELS), lung assessment, pleural effusion, and rapid cardiac echo improves utility out-of-hospital.

The ultrasound course was developed to address a gap in out-of-hospital ultrasound education. The course modules emphasise patient and clinician safety, while the clinician's employer is responsible for ultrasound use and implementation. The author recognised this need and proposed a Certificate in Prehospital Performed Ultrasound (CPPU) to ASUM. The ASUM community has positively responded, and the AUT ultrasound course accreditation efforts are ongoing. The refined structure is proposed using modules, including 'Critical Care,' 'Community' and 'Practitioner', each building on the previous module. As illustrated in Figure 70 this format offers a clear breakdown of each module and the corresponding weeks of study. This structure paves the way for the ultrasound credentialing of out-of-hospital providers, extending beyond paramedics to nurse practitioners and rural doctors. ASUM would oversee this credentialing process.

The author was invited by ASUM faculty to present the CPPU proposal at their annual congress in Sydney, Australia, on October 14th, 2023. An abstract for 'Certificate in Prehospital Performed Ultrasound (CPPU): Aligning with Prehospital Practice Requirements' was accepted and is shown in the next section as the ASUM Annual Congress CPPU Abstract.

Figure 70

Certificate in Prehospital Performed Ultrasound Modules



Note. Screen capture from CPPU proposal presentations using PowerPoint Software.

5.10 ASUM Annual Congress CPPU Abstract

Title. Certificate in Prehospital Performed Ultrasound (CPPU): Aligning with out-of-hospital requirements.

Introduction. Point-of-care ultrasound (POCUS) has rapidly evolved and has been adopted by many medical specialities, including paramedicine. Out-of-hospital professionals increasingly use POCUS to answer focused clinical questions. This leads to quicker and more precise diagnoses and treatment for patients with conditions requiring immediate attention. However, comprehensive POCUS frameworks are essential to ensure the highest clinical quality and safety standards. A Certificate in Prehospital Performed Ultrasound (CPPU)

specific to the paramedic scope is needed to progress the safe implementation and continued practice of ultrasound out-of-hospital.

Purpose. To introduce an ASUM Certificate in Prehospital Performed Ultrasound (CPPU) aligned with out-of-hospital and paramedic practice requirements by merging current modules from CAHPU and CCPU tailored to critical and community care and practitioner level. Out-of-hospital ultrasound improves diagnostic ability, facilitating targeted clinical management, early recognition of surgical emergencies, and appropriate destination decisions for trauma and medical patients. Improved outcomes have been documented through the utilization of ultrasound in out-of-hospital settings. The CPPU aims to address the shortcomings of ultrasound, such as paramedic ultrasound experience and interpretation errors. The Auckland University of Technology's ultrasound course provides a foundation for CPPU accreditation.

Conclusion. The introduction of a CPPU signifies the progression of ultrasound practice in paramedicine. It provides a tailored pathway for practitioners to upskill and gain accreditation in out-of-hospital ultrasound. The CPPU aims to address the shortcomings of ultrasound and emphasizes the importance of governance, infrastructure, administration, education, and quality. The benefits of ultrasound out-of-hospital, such as improved diagnostic ability and targeted clinical management, are well-established. The ultrasound course at AUT provides a solid foundation for those wishing to gain certification in out-of-hospital ultrasound. The CPPU represents a significant step towards improved patient outcomes in out-of-hospital and paramedic practice.

5.11 Wellington Free Ambulance Ultrasound Introduction

Wellington Free Ambulance has initiated an ultrasound pilot program involving four flight paramedics. As a flight Paramedic, the author will work directly with this select group, making them an ideal cohort to test the CPPU concept. The pilot project uses the Lumify ultrasound device, which features remote uploading via Tricefy, a cloud medical imaging platform, and Reacts cell phone software. Reacts software provides video calling for remote clinical support. Throughout the program, flight paramedics must maintain a logbook and undergo summative and formative evaluations based on ASUM CAHPU criteria. Following the pilot program, WFA aspires to integrate ultrasound into broader paramedic practices, with ECPs poised as the next group for implementation. Establishing clinical governance, the need for regular audit and review processes, and the provision of ongoing education are in development at the time of writing. Additionally, the financial burden of procurement and maintenance of ultrasound equipment is still unresolved.

5.12 Recommendations For Future Research

Operational Setting. Research investigating how strategies from the CAFE trial work when applied in real-world operational settings. Are there any logistical or practical barriers that were not apparent in the controlled environment of a trial?

Sample Size and Population. Future studies should aim to have a larger sample size and be more representative of the population to enhance the generalisability of the findings.

Quantification of Low Flow Output. Investigate advanced measurement techniques for quantifying low flow states, potentially using arterial lines as markers for initiating targeted vasopressor treatment. This will assess the reliability and effectiveness of these methods in out-of-hospital settings.

Outcomes and Clinical Significance. The critical question remains: “Does the recognition of pseudo-PEA low flow states improve survival outcomes, or does it simply lead to intensive care unit admissions for patients unlikely to survive hospital discharge?”. Studies should aim to tackle this ethical and clinical dilemma by looking at both short-term and long-term outcomes.

Chapter 6 Conclusion

This study set out to establish whether paramedics could acquire and interpret an ultrasound image during pulse check pauses in a simulated PEA cardiac arrest. Observation, education, and simulation were methods used to explore the objective. This research demonstrated that with minimal training, paramedics averaged 9.6 seconds to perform an ultrasound during simulated cardiac arrests. However, only 47.7% of scans were within the strict 9.99-second time limit. Difficulties obtaining an echo view contributed to delays in hands-off time, suggesting specific training to improve adherence. While the current ultrasound experience by paramedics in New Zealand is minimal, increasing its use in everyday practice is anticipated to improve ultrasound skills and competence.

Secondary aims focused on ultrasound image quality and image interpretation abilities. Paramedics acquired good images; with time, their proficiency and image quality are expected to improve. Despite the condensed learning, the image quality was fair, and paramedics demonstrated strong interpretation skills with minimal training. Overall, participants' image interpretation exceeded 90%, indicating a high level of proficiency. However, there are opportunities for improvement, particularly in evaluating left ventricular squeeze. These findings complement those of previously published studies showing that paramedics perform well when asked to evaluate pericardial effusion, tamponade, left ventricular squeeze, valvular movement and the presence or absence of a heartbeat. Paramedics demonstrated adequate knowledge and retention; however, only 67.2% achieved the specified pass mark (≥ 80%), indicating areas for improvement in education delivery, design, and testing methods.

The broader translation of ultrasound technologies into New Zealand paramedic clinical practice in the out-of-hospital setting is yet to be established. However, providing

real-time information during active resuscitation is invaluable, especially when traditional methods of ROSC detection for pseudo-PEA are indeterminate. Once ultrasound becomes part of paramedic practice, consolidating knowledge, skills and familiarisation with the equipment should improve ultrasound competence. Ultrasound use in cardiac arrest emergencies should aim to improve patient assessment accuracy, provide insight for differential diagnoses, and guide treatment and transport decisions, complementing the current skills employed in answering the questions of the P-PEAT algorithm.

Given the increasing occurrence of PEA in cardiac arrest, evaluating for pseudo-PEA is critical for improving patient survivability. Suggestions for future research focus on the efficacy of ultrasound in determining pseudo-PEA and the possibility of integrating algorithms such as P-PEAT.

Overall, this research has demonstrated that paramedics can learn and integrate ultrasound into the pulse check pause, acquire good-quality images, interpret findings accurately and retain specific knowledge. With regular ultrasound use and increasing familiarity, speed and proficiency in POCUS are anticipated to improve.

Appendix A

Auckland University of Technology Ethics Approval Letter



Auckland University of Technology Ethics Committee (AUTEC)

Auckland University of Technology
D-88, Private Bag 92006, Auckland 1142, NZ
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

30 November 2021

Bronwyn Tunnage
Faculty of Health and Environmental Sciences

Dear Bronwyn

Re Ethics Application: **21/327 Integration of paramedic-led echocardiography in pulseless electrical activity (PEA) at out-of-hospital cardiac arrests: An education and simulation study.**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 30 November 2024.

Standard Conditions of Approval

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
7. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard and that all the dates on the documents are updated.
8. AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted and you need to meet all ethical, legal, public health, and locality obligations or requirements for the jurisdictions in which the research is being undertaken.

Please quote the application number and title on all future correspondence related to this project.

For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

(This is a computer-generated letter for which no signature is required)

The AUTEC Secretariat
Auckland University of Technology Ethics Committee

Cc: Hannah.latta@aut.ac.nz; Andrew Swain

Appendix B

Wellington Free Locality Ethics Approval

Wellington Free Ambulance (WFA) Locality Research Application Form

The survey will take approximately 13 minutes to complete.
All research, and/or data extract requests that may involve; or be in collaboration with WFA, patients, staff and/or facilities must be registered with WFA for approval. Staff undertaking such activities should make themselves familiar with the requirements of the Privacy Act 1993 and the Health Information Privacy Code 1994. The Privacy Act sets out 12 Principles that govern the collection, use, storage, retention and disclosure of personal information. The Privacy Act also permits the Privacy Commissioner to issue codes of practice governing particular types of personal information. In 1994 the Commissioner issued the Health Information Privacy Code . This Code contains 12 Health Information Privacy Rules . The Rules are very similar to the 12 Principles in the Privacy Act but are modified specifically for the health sector. Please use the following form to register your aplication. If you have any queries regarding this please e-mail Clinica 1Services@wfa.org.nz (mailto: Clinica 1Services@wfa.org .nz)

* Required

1. Title of Research *

Integration of paramedic-led echocardiography in pulseless electrical activity (PEA) at out-of-hospital cardiac arrest: An education and simulation study.

2. Contact Information - Name*

Hannah Latta

3. Contact Information - Organisation

Wellington Free Ambulance

4. Contact Information - E-mail Address *

Hannah.latta@aut.ac.nz

5. Contact Information - Phone number*

0273193630

6. Contact Information - Physical Address (Street Address: City/Town: Postcode: Country) *

16 Stemhead Lane, Whitby, Porirua 5024

7. Contact Information - Postal Address (if different from the above) *

8. Scope of Your Request -
What is the aim of your project/request and its key objective(s)? For example, to compare treatment regimes, evaluate service provision etc. *

The overarching research question is:

Can paramedics acquire and interpret Cardiac Arrest Focused Echocardiography (CAFÉ) during the pulse check pauses in pulseless electrical activity (PEA) at simulated cardiac arrests?

In order to investigate this question, the research will assess the following secondary questions to establish whether paramedics can within the 10-second pulse check pause:

1. Demonstrate ultrasound acquisition (Phase II and III: Echo Skills Assessment)
2. Achieve echo images that are adequate for interpretation with a CUSAS Score of ≥3 (Phase II and III: CAFÉ Exam Integration Simulations)

and, within the two-minute CPR cycle:

3. Accurately identify the presence of pseudo-PEA and true PEA (Phase II and III: Online Knowledge Test and CAFÉ Exam Integration Simulations)
4. Accurately identify cardiac tamponade (Phase II and III: Online Knowledge Test and CAFÉ Exam Integration Simulations)

To investigate the research questions the method involves three phases. These include pre-education, didactic and hands-on training, and assessment. These are outlined in the methods section.

9. Will any of the information contained in the WFA dataset be published or disclosed to any other person? Outline the manner and circumstances of publication or disclosure. *

No. Aggregated data will be published.

10. Will the outputs from use of the WFA dataset be shared with WFA? *

The outcomes will be published and available to WFA staff.

11. Will WFA be free to use outputs from the use of WFA data for its own activities? *

Not without prior permission and consent from the author. Material in the public domain e.g. research findings from publications, may be used freely.

12. Will any individual be identifiable at any stage including during data collection and analysis or as a result of the outputs of processing? Outline the manner or circumstances in which individuals may be identifiable and what steps will be taken to protect their privacy. *

The lead researcher will be blinded to participant performance through the use of a study identification number assigned by Dr Bronwyn Tunnage (Research Supervisor). Once the data has been synthesized and published, the study participants may wish to know their results. The study identification number at this point can be matched to the study participant name and information provided.

13. How do you propose to access or have the information transferred to you? Please include whether you will require access to WFA record/LT. systems. *

Information is provided by the study participant and data recorded from assessments and quizzes.

No WFA data is required.

14. How will the WFA data be stored and secured?*

In Phases II and III, ultrasound images taken during the assessments (using healthy volunteers) will be stored on the ultrasound device and downloaded to AUT OneDrive as a DICOM (digital imaging and communications in medicine) file. Images will be viewed using a DICOM reader.

The research material including scans and assessments will be stored on the lead researcher's AUT OneDrive. This data will also be saved on a hard drive labelled 'CAFE Research Back Up' which will be stored physically at Life Flight in a secure locked safe. This drive will be backed up once a week.

15. Who will have access to the WFA dataset? *

Research team:
Hannah Latta
Dr Bronwyn Tunnage
Dr Andy Swain

External Moderators
Dr Scott Bomann (also research team)
Dr Kelvin Ward (TBC)

16. Are there any plans for future use of the data beyond those already described? *

None

17. For how long will the data be kept? *

10 years

18. How will the data be destroyed? *

Hard drive wiped and digital data deleted

19. Will any data be transferred outside New Zealand? (If so, please list the countries and the circumstances of transfer). *

No

20. Will a subcontractor or other third party be appointed to process any of the data? If so, list the party and its role. *

Yes, Dr Kelvin Ward, Lead Physician for Point-of-Care Ultrasound, After-Hours Medical Centre, Wellington (TBC) as part of external moderation process.

21. What type of ethics approval will/has been sought? To clarify ethics requirements, please refer to the guidelines at www.ethics.health.govt.nz (httP-://www.ethics.health.govt.nz). *

D No ethics review is required

D Health and Disability Ethics Committee (HDEC) review

D Non-HDEC review (e.g. university ethics committee)

D Not sure

22. What is the legal basis for your request?
Rule 11 of the Health Information Privacy Code and the Health Act 1956 provide a framework for when information can be disclosed . Refer to the code here:
https://www.Privacy.org.nz/Privacy-act-2020/codes-of-Practice/hiP-c2020/
and sections 22B to 22 H of the Health Act here:
https://www.legislation.govt.nz/ act!Public/1956/ 0065/latest/DLM305840.html#DLM30667
or contact our team for assistance. *

O The data is being requested on behalf of a healthcare provider who will use it for the purposes of continued patient care

O The data is being requested for research purposes and will not be published in a form that could reasonably be expected to identify the individual/s concerned

23. Have you consulted with anyone from WFA regarding your project? If so, please provide their names. *

Dr Andy Swain

24. Please check the following have been emailed to ClinicalServices@wfa.org.nz .(mailto:ClinicalServices@wfa.org.nz). *

D Project protocol/proposal (Aim, Methodology, Data analysis, Evaluation)

0 Are you requesting data? If so, please complete and upload the data request form available here: https://www.surveymonkey.com/r/WFAdatasharingchecklist

0 Full ethics application form. If your project involves participants please also append the following documents to your full ethics application form: Participant information sheet, Participant consent form, Participant recruitment information (advertisement/letter of invitation) .

☐ Ethics: please provide a copy of the ethics approval letter or upload a short statement as to why this is not required. Note that whilst external ethics committee approval may not be required all QI and Audit activities must comply with the NEAC guidelines found here: https://neac.health.govt.nz/ Publications-and-resources/neac-Publications/ national-ethical-standards-health-and-disability_

☐ Funding contract

☐ Evidence of cultural consultation. If your request is for research you must include evidence of Cultural Consultation

☐ Privacy Impact Assessment Document. Please complete the Brief Privacy Analysis document (template 1) available at https://www.privacy.org.nz/assets/LEGACY-FILES/Guidance /Template-1-Brief-Privacy-Analysis-Part-1-Appendix-A.docx

25. Does this study relate to an existing or previous study registered with WFA? If so, please state the study title and Principal Investigator's name. *

No

26. If access for this request is granted, I understand my responsibilities and will ensure compliance with my obligations. In particular if this request is for clinical records, these will only be used for the purposes outlined within the scope of this form and all records will be maintained securely and in accordance with the Health and Information Privacy Code 1994 and subsequent amendments. If the project is authorised, the project title, project outline and principal investigator may be listed on a publicly available research register.
Responsible Contact: ENTER FIRST NAME AND LAST NAME BELOW*

Hannah Latta

27. Enter today's date dd/mm/yyyy *

06/12/2021

APPROVED



Dr Andy SWAIN
Medical Director, WFA.
07/03/2022

APPROVED



Paul Fake
Executive Director Qulity Improvement and Innovation
07/03/2022

Microsoft Forms
This content is neither created nor endorsed by Microsoft. The data you submit will be sent to the form owner.

Appendix C

Data and Privacy Analysis

PART 1 APPENDIX A: TEMPLATE – BRIEF PRIVACY ANALYSIS

Tailoring this template to your own project

- Add your own branding and formatting throughout this document.
- Review the list of questions and risks in sections 2.1 and 2.2 of the template to suit your organisation and project.
- If your organisation has written policies, procedures or guidelines on privacy, you could add these as a background reference section at the end of the document.
- Update the sign-off list in section 5 to include:
  - people who should be involved in preparing and reviewing the document (for example the project manager)
  - people who need to review and approve the document (for example, the privacy officer).

CAFE TRIAL
Brief Privacy Analysis

03 December 2021

1. Project summary:

Integration of paramedic-led echocardiography in pulseless electrical activity (PEA) at out-of-hospital cardiac arrests: An education and simulation study.

1.1 Brief description of the project

a) Describe your existing systems and the main changes that are proposed:

This is a simulation trial researching the ability of paramedics to learn and apply focused cardiac arrest ultrasound in simulated Pulseless Electrical Activity (PEA).

b) Describe the purpose of the change, including any projected benefits to your organisation or to the individuals affected:

Benefits:
Paramedics - include learning a new skill, contributing to informing a knowledge gap within paramedic PEA cardiac arrest ultrasound literature and exposure to the practical element of research.
Volunteer – Being involved with facilitating practical sessions, experiencing ultrasound first hand and having an opportunity to be part of a research project.

c) Identify the main stakeholders or entities involved, and their role in the project.

1. *Auckland University of Technology – academic oversight*
2. *Wellington Free Ambulance – research platform (participants and volunteers)*
3. *Wellington Emergency Department/CCDHB – simulation suite facilities and study assessors/mentors.*
4. *Life Flight Air Rescue Centre – access to a secure database if required.*
5. *Philips – loaned ultrasound devices.*

1.2 Personal information that the project will involve

In the table below, describe:

- the personal information that will be collected, used and/or disclosed
- the source of the information
- the purpose of the information for your project.

Note: "Personal information" is any information about an identifiable living person. However, a person doesn't have to be named in the information to be identifiable.

Type of personal Information	Source of Information	Purpose of information for the project
Name*	Participant	Provide feedback of final results to the participant.
Demographic Data	Participant	Determine variables within the participant group, e.g. age, sex, paramedic grade.
Ethnicity	Participant	To assess spread of ethnicity within the study group against national norm.

*The participant name will be collected by Dr Bronwyn Tunnage and aligned with a study Identification number. The lead researcher Hannah Latta has access to the study identification number only and is therefore blinded to the data. Names will allow results to be shared with individual participants at the end of the project.

2. Privacy assessment

2.1 Areas that are risky for privacy

Some types of projects are commonly known to create privacy risks. If the project involves one or more of these risk areas, it's likely that a PIA will be valuable.

Use this checklist to identify and record whether your proposal raises certain privacy risks. Delete any that do not apply.

Does the project involve any of the following?	Yes (tick)	No (tick)	If yes, explain your response
Information management generally			
A substantial change to an existing policy, process or system that involves personal information ***Example**: New legislation or policy that makes it compulsory to collect or disclose information*		✓	
Any practice or activity that is listed on a risk register kept by your organisation ***Example:** Practices or activities listed on your office's privacy risk register or health and safety register*		✓	
Collection			
A new collection of personal information ***Example:** Collecting information about individuals' location*		✓	
A new way of collecting personal information ***Example:** Collecting information online rather than on paper forms*	✓		The participant will enrol with AUT for Phase I eLearning Module. Demographic data will be collected such as name, age, sex and time in current ATP.
Storage, security and retention			
A change in the way personal information is stored or secured ***Example:** Storing information in the cloud*		✓	
A change to how sensitive information is managed		✓	

Does the project involve any of the following?	Yes (tick)	No (tick)	If yes, explain your response
Example: *Moving health or financial records to a new database*			
Does the project involve any of the following?	**Yes (tick)**	**No (tick)**	**If yes, explain your response**
Transferring personal information offshore or using a third-party contractor ***Example:*** *Outsourcing the payroll function or storing information in the cloud*		✓	
A decision to keep personal information for longer than you have previously ***Example:*** *Changing IT backups to be kept for 10 years when you previously only stored them for 7*		✓	
Use or disclosure			
A new use or disclosure of personal information that is already held ***Example:*** *Sharing information with other parties in a new way*		✓	
Sharing or matching personal information held by different organisations or currently held in different datasets ***Example:*** *Combining information with other information held on public registers, or sharing information to enable organisations to provide services jointly*		✓	
Individuals' access to their information			
A change in policy that results in people having less access to information that you hold about them ***Example:*** *Archiving documents after 6 months into a facility from which they can't be easily retrieved*		✓	
Identifying individuals			

Does the project involve any of the following?	Yes (tick)	No (tick)	If yes, explain your response
New intrusions on individuals' property, person or activities			
Introducing a new system for searching individuals' property, persons or premises ***Example:*** *A phone company adopts a new policy of searching data in old phones that are handed in*		✓	
Surveillance, tracking or monitoring of movements, behaviour or communications ***Example:*** *Installing a new CCTV system*		✓	
Changes to your premises that will involve private spaces where clients or customers may disclose their personal information ***Example:*** *Changing the location of the reception desk, where people may discuss personal details*		✓	
New regulatory requirements that could lead to compliance action against individuals on the basis of information about them ***Example:*** *Adding a new medical condition to the requirements of a pilot's license*		✓	
List anything else that may impact on privacy, such as bodily searches, or intrusions into physical space	✓		The volunteer model will expose their upper abdomen and small portions of the chest (left side) will be exposed to perform ultrasound. Females will be asked to wear a crop top and privacy is maintained using screens and appropriately placed blankets. All volunteer models will be consented into this process.

2.2 Initial risk assessment

If you answered "Yes" to any of the questions above, use the table below to give a rating – either **Low (L)**, **Medium (M)**, or **High (H)** – for each of the aspects of the project set out in the first column.

For risks that you've identified as Medium or High, indicate (in the right-hand column) how the project plans to lessen the risk (if this is known).

If you answered "No" to all the questions in 2.1 above, move on to section 3 below.

Aspect of the Project	Rating (L, M or H)	Describe any medium and high risks and how to mitigate them
Level of information handling L – Minimal personal information will be handled M – A moderate amount of personal information (or information that could become personal information) will be handled H – A significant amount of personal information (or information that could become personal information) will be handled	L	Standard demographic and ethnicity data for describing the research population.
Sensitivity of the information (eg health, financial, race) L – The information will not be sensitive M – The information may be considered to be sensitive H – The information will be highly sensitive	L	Ethnicity for deviations from the norm.
Significance of the changes L – Only minor change to existing functions/activities M – Substantial change to existing functions/activities; or a new initiative H – Major overhaul of existing functions/activities; or a new initiative that's significantly different	L	

Interaction with others L – No interaction with other agencies M – Interaction with one or two other agencies H – Extensive cross-agency (that is, government) interaction or cross-sectional (non-government and government) interaction	L	Participants, volunteers, assessors and research staff.
Public impact L – Minimal impact on the organisation and clients M – Some impact on clients is likely due to changes to the handling of personal information; or the changes may raise public concern H – High impact on clients and the wider public, and concerns over aspects of project; or negative media is likely	L	No public impact

3. Summary of privacy impact

The privacy impact for this project has been assessed as:	Tick
Low – There is little or no personal information involved; or the use of personal information is uncontroversial; or the risk of harm eventuating is negligible; or the change is minor and something that the individuals concerned would expect; or risks are fully mitigated	✓
Medium – Some personal information is involved, but any risks can be mitigated satisfactorily	
High – Sensitive personal information is involved, and several medium to high risks have been identified	
Reduced risk – The project will lessen existing privacy risks	
Inadequate information – More information and analysis is needed to fully assess the privacy impact of the project.	

3.1 Reasons for the privacy impact rating

Briefly summarise your reasons for the rating you gave above.

We are collecting minimal personal information required only to describe the study population and compare variables within the research data.

4. Recommendation

Do a full privacy impact assessment

Describe:
- the likely timing of the PIA
- the level of complexity that will be needed
- who will be responsible for doing the PIA

or

A full privacy impact assessment is not required.

Explain why a PIA is not needed

No participant or volunteer personal information will be shared outside the study and that recorded for the study will be anonymised and aggregated for research papers.

5. Sign off

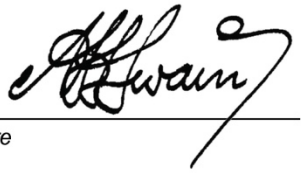
Hannah Latta
Name


Signature

Flight ICP
Position (Project Manager)

07 / 03 / 2022
Date

Dr Andy SWAIN
Name


Signature

Medical Director, WFA.
Position (Manager)

07 / 03 / 2022
Date

Appendix D

Mātauranga Māori Committee Consultation Approval



School of Clinical Sciences
Mātauranga Māori Committee

Verification of Māori Consultation

This document provides verification that the research project named below was discussed with the School of Clinical Sciences Mātauranga Māori Committee, Auckland University of Technology. Specific comments and recommendations are indicated following the table.

Title of project: "Out-of-hospital cardiac arrest focused echocardiography in pulseless electrical activity (PEA) – A prehospital observational trial"		
Research Team members and affiliations: Hannah Latta- Ngāpuhi affiliation by partner and son, AUT DHSc Candidate; Dr Bronwyn Tunnage-AUT Supervisor; Assoc Prof Andrew Swain-AUT Supervisor; Dr Scott Bomann-Specialist Advisor, Wellington Hospital.		**Meeting Date:** **4/11/2020**
Discussion Areas		**Discussed**
Whakapapa: Relationships		
Researcher experience in field		X
Consultation with local stakeholders		x
Consenting process		x
Clarity of data usage		x
Dissemination of findings		x
Benefits to participants		x
Protecting the rights & interest of Māori		
Clear purpose of project		X
Relevance to Māori		x
Likely outcome for participants, communities, other stakeholders		x
Participant recruitment methods		x
Māori involvement in project (participants, researchers, etc.)		x
Cultural & Social Responsibility		
Participants' access to appropriate advice		
Participants treated with dignity and respect		x
Privacy and confidentiality		x
Whānau support		
Transparency of research process		x
Mana tangata – Power & Authority		
Reciprocity (acknowledgements, compensation, gifts)		x
Risks of participation identified		x
Ownership of outcomes		x
Informed consent process		x

Comments / clarifications

1.	This is a three-phase study. Phase 1 and 2 are training and competency assessment components, training participating paramedics to perform and interpret ultrasound assessments. Phase 3 is an observational trial where the trained supernumerary paramedics will perform the ultrasound assessments during out-of-hospital cardiac arrest (OHCA). Māori are over-represented in OHCA statistics, so it is of direct relevance to Māori.
2.	This is a purely observational study. Whatever is observed by ultrasound will not be conveyed to those conducting the resuscitation – usual protocols will continue. The project is looking to obtain the data on how common pulseless electrical activity is and determine if the current resuscitation algorithm protocols could be improved by the addition of the ultrasound check.
3.	Cultural safety information will be included in the training and the research team this as an opportunity to improve on the cultural resources and training that currently available in the ambulance service.
4.	Current resuscitation practice involves exposure of the person's chest for safety and diagnostic reasons. Introduction of the ultrasound assessment will involve the addition of ultrasound gel. The probe equipment and monitoring equipment are very discreet.
5.	Consent from the person undergoing resuscitation cannot be sought at the time of ultrasound. However, permission will be sought from whānau – i.e., explaining why the researchers are doing what they are doing and checking that that is OK.
6.	Data from the project will be given to Te Mana Raraunga with the intention of making sure that the data and findings are available to Māori.

Recommendations made by Committee

1.	Involving Māori in the early phases of the project will be a prime opportunity to engage and support Māori and to demonstrate its applicability to Māori when/if it comes to implementation of the new process.
2.	The committee support taking the opportunity to improve cultural training.
3.	The committee would strongly advise including Māori paramedics and healthy volunteers in the early phases of the project and to seek their feedback on the ultrasound protocol to help understand how the protocol may be perceived by whānau. Talking with Kaumātua about the project would optimise the likelihood that the ultrasound protocol will be culturally responsive prior to doing the Stage 3 research.
4.	Talking with the Māori liaison for Wellington Free Ambulance and St Johns would also be useful.
5.	Communication was highlighted as key for Māori – the need to explain what is being done, why, and what is expected from that action, so that whānau understand exactly what is being undertaken and why. Communication with whānau should be an important factor to include in training. It is also important to prioritise the dignity of the person involved.

6.	The committee noted that it would be good practice to retrospectively acknowledge the whānau / patient, thanking them for the gift of their knowledge. Ideally this would be done face-to-face, or if that was not possible by letter, to thank the family.
7.	Advice from the committee about questions such as "what is the right thing to do about gel left on the body if resuscitation is ceased?" is to talk with the respective whānau – they will tell you what to do. Similarly, when there are multiple family members on the scene, look to the more mature person in the group and ask who the key person to talk with is.
8.	The committee acknowledged the sharing of data with Te Mana Raraunga and noted that involving Māori early on will also support better relationships to allow easier dissemination of results.

Please contact the Committee's Administrator Greta Smith at socs-mmc@aut.ac.nz if you have any questions about this feedback.

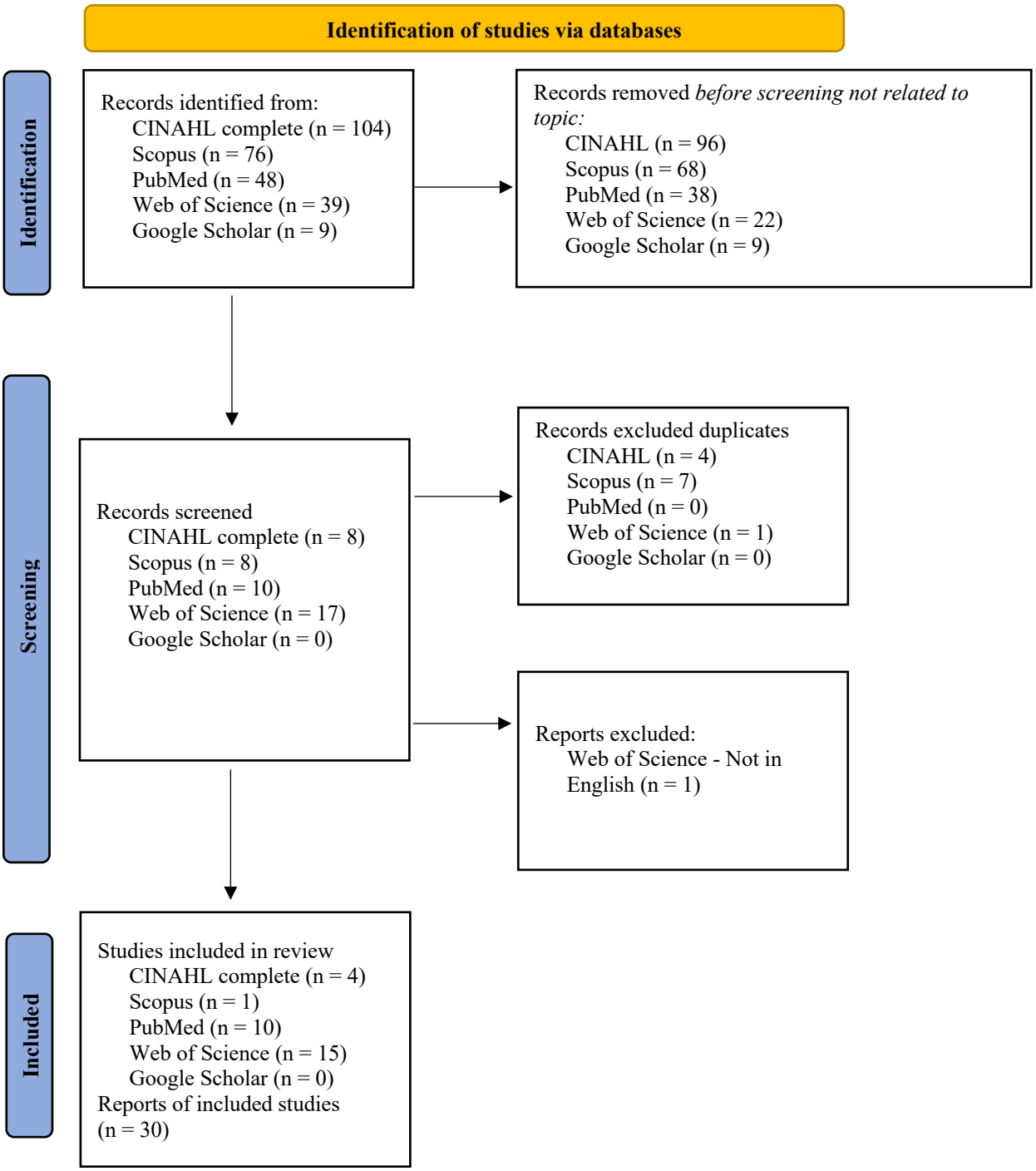
You may be contacted in 12 months' time for feedback about the process and the usefulness of these comments and recommendations to your project.

Signature:  5/11/2020

Grant Mawston
Mātauranga Māori Consultation Committee

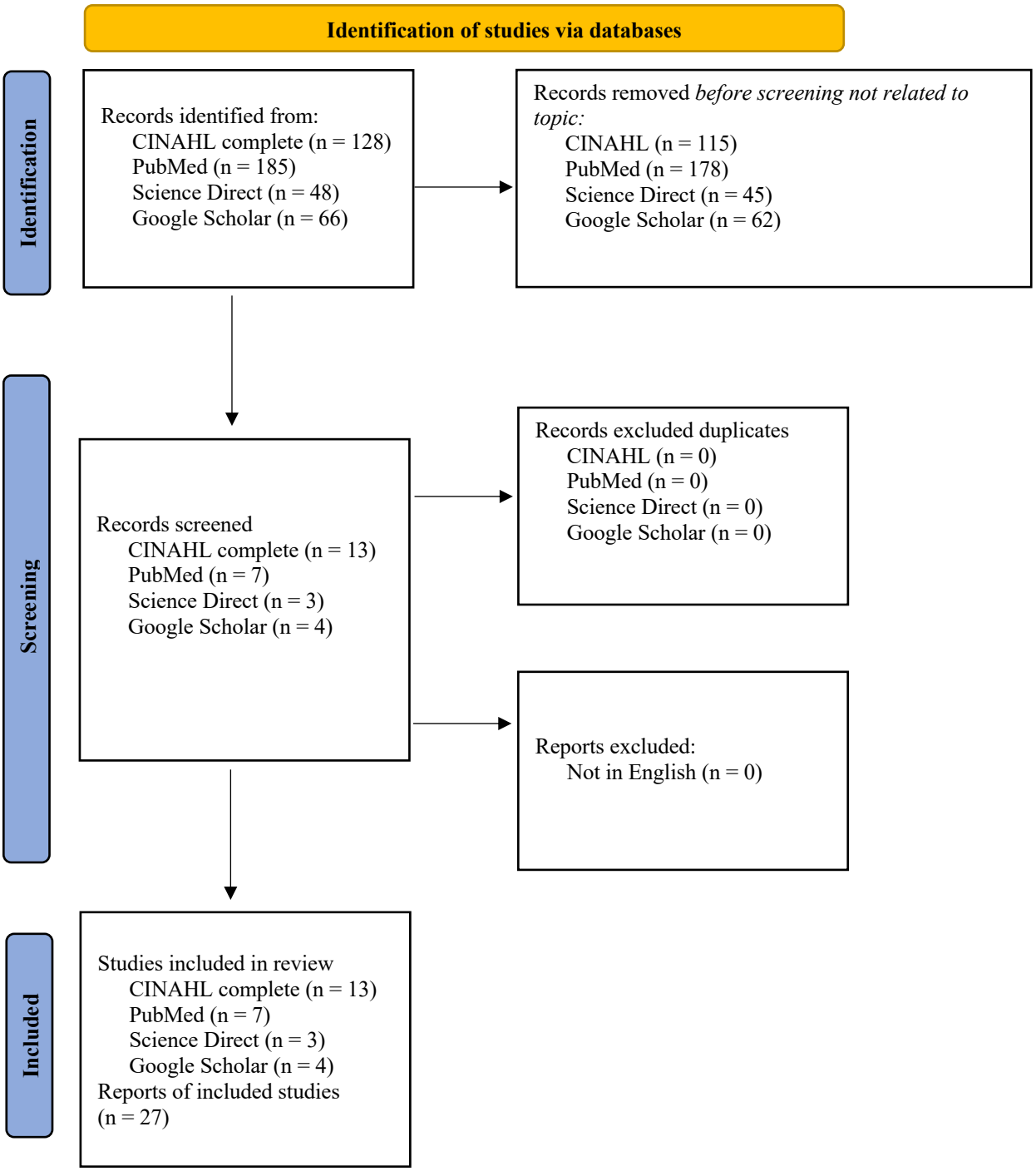
Appendix E

PRISMA Flow Diagram OHCA-PEA Literature Review



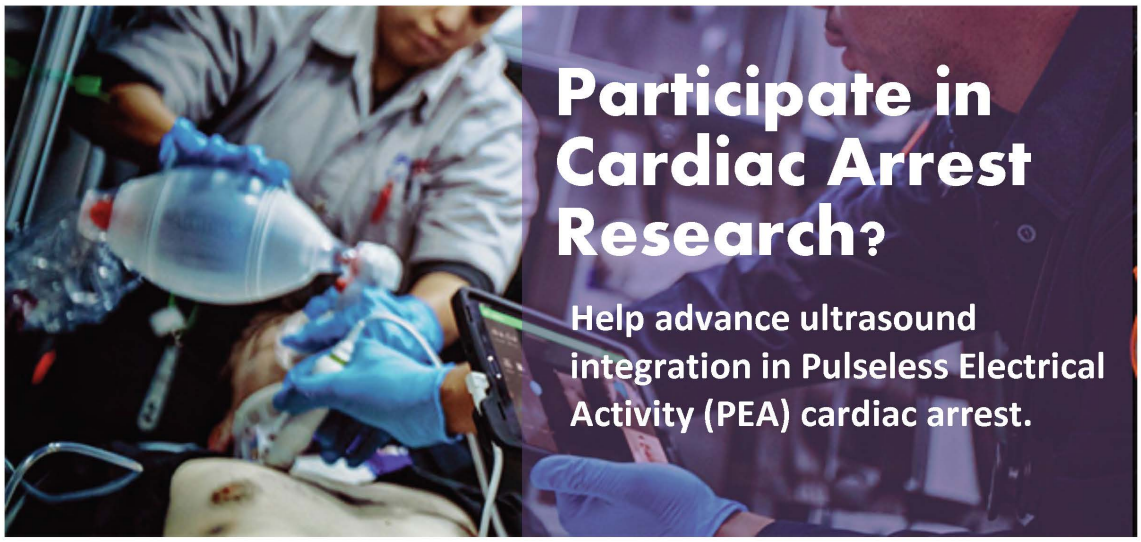
Appendix F

PRISMA Flow Diagram Ultrasound Education



Appendix G

Study Advertisement Paramedics



Cardiac Arrest Focused Echo - (CAFE) trial
Integration of paramedic-led echocardiography in pulseless electrical activity (PEA) at out-of-hospital cardiac arrests: An education and simulation study.

There are three phases to the CAFE research trial. As a participant, you will be asked to participate in all three phases of the study.

- Phase I :2-hr online education module
- Phase II: 6-hr hands-on training and assessment
- Phase III: 1-hr assessment

Are you eligible?

To be eligible, you must be:

- Paramedic level or above
- Registered
- BHSc or equivalent
- Working frontline

Exclusion criteria:
Previous clinical ultrasound experience

You will be asked to learn the basics of echo ultrasound, safety, cultural awareness integrated into prehospital cardiac arrest.

AUT UNIVERSITY
TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

CAFE
CARDIAC ARREST FOCUSED ECHO

Register your interest and receive more info from:

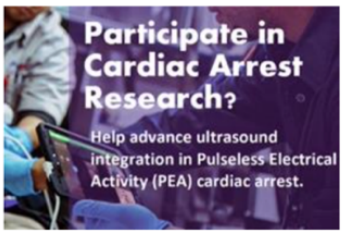
CAFE.research@wfa.org.nz

Appendix H

Keeping Connected Staff Bulletin Group A

Research opportunity

Intensive Care Paramedic **Hannah Latta** is currently completing a Doctoral of Health Science through Auckland University of Technology (AUT) researching the use of ultrasound in cardiac arrest.



Hannah would like to extend an invitation for you to participate in her research project: ***"Integration of paramedic-led echocardiography in pulseless electrical activity (PEA) at out-of-hospital cardiac arrests: An education and simulation study".***

The invitation extends to two streams of participants:

1) Paramedics to participate in the research learning and performing Cardiac Arrest Focused Echo exam (CAFE exam)
and
2) Volunteers to help with simulation and act as healthy subjects for the participants to practice ultrasound on.

For more information on *who is required*, *what will be involved* and *how you can apply* please read on SharePoint here.
See flyers on healthy volunteers here and one on participants here. These will be displayed around station.

The closure of invitations is **1 January 2022**. However, if there is not enough interest this date may be extended.

Learning and Professional Development

Spinal Management and Car Extrication Training
The clinical education team would like to offer WFA staff the opportunity to attend traumatic spinal management and car extrication training with WFA and FENZ. The training can be used for CPD and certificates of attendance will be issued. We are not able to pay for your attendance and training is located in Lower Hutt. Please follow this link to sign up via ELMO : **ELMO at WFA (elmotalent.co.nz)**



Upcoming dates: 23 April, 7 May, 13 Aug, 8 Oct and 22 Oct.

Ultrasound in Cardiac Arrest Research Trial a Huge Success

GROUP B – Recruiting now open!
We have successfully completed our first round (Group A) of the ultrasound trial. Thank you to everyone involved. It was a fantastic time and I'm sure Group A will share their experiences. During Phases I and II, the participants learnt about the physics of ultrasound, how to use the ultrasound device and perform echo ultrasound in cardiac arrest. On the training day we had five doctors running ultrasound stations and 10 volunteers as healthy subjects and simulation operators. The doctors were amazed at how quickly the paramedics picked up ultrasound and the quality of images acquisition was fantastic. I was excited for the participants. The assessment day was not without hiccups with a sudden change from the Wellington Sim Lab to a hall in Tawa. However, in true style everyone rose to the occasion and the day went well.

Would you like to learn echo ultrasound or volunteer?
We are holding a second trial (Group B) recruiting in the month of April. Phase I and II will be in May and Phase III in June. The dates are free and clear for red and green shift (sorry brown). More information is available **here** for participants, and **here** for healthy volunteers. A video with further details can be viewed **here**.

Please email **CAFE.research@wfa.org.nz** for an information sheet. We would love to have you.

Appendix I

Keeping Connected Staff Bulletin Group B

Ultrasound in Cardiac Arrest Research Trial a Huge Success

GROUP B – Recruiting now open!

We have successfully completed our first round (Group A) of the ultrasound trial. Thank you to everyone involved it was a fantastic time and I'm sure Group A will share their experiences. During phase I and II, the participants learnt about the physics of ultrasound, how to use the ultrasound device and perform echo ultrasound in cardiac arrest. On the training day we had five doctors running ultrasound stations and 10 volunteers as healthy subjects and simulation operators. The doctors where amazed at how quickly paramedics pick up ultrasound and the quality of images acquisition was fantastic. I was excited for the participants. The assessment day was not without hiccups with a sudden change from the Wellington Sim Lab to a hall in Tawa. However, in true style everyone rose to the occasion and the day went well.

Would you like to learn echo ultrasound or volunteer?

We are holding a second trial (Group B) recruiting in the month of April. Phase I and II will be in May and Phase III in June. The dates are free and clear for red and green shift (sorry brown). Please send me an email via CAFE.research@wfa.org.nz and I'll reply with an information sheet. We would love to have you.

Phase II



Echo Practice



Study Participants



Cardiac Arrest Simulation



Appendix J

Information Sheet and Consent Form All Participants



Participant Information Sheet

Date Information Sheet Produced: 27 August 2021

Project Title

Integration of paramedic-led echocardiography in pulseless electrical activity (PEA) at out-of-hospital cardiac arrests: An education and simulation study.

Project Identifier

The study is called the "Cardiac Arrest Focused Echo" (CAFÉ) exam.



An Invitation

My name is Hannah Latta. I am an intensive care flight paramedic and doctoral student at the Auckland University of Technology. I would like to invite you to participate in my research project. Participants are being sought from Wellington Free Ambulance (WFA).

What is the purpose of this research?

In a PEA cardiac arrest, the patient has no palpable pulse. The electrical impulse that stimulates the heartbeat is present, but the heart muscle does not respond. Research reveals that up to 75% of Out-of-Hospital Cardiac Arrest (OHCA) patients in PEA are found to have a heartbeat when examined with an ultrasound scan. However, the heartbeat in this pseudo-PEA state is too weak to generate a palpable pulse and instead of resuscitation being attempted, the patient may be declared dead.

A paramedic-led ultrasound scan of the heart during PEA allows the user to see a real-time image. This image answers the focused clinical questions of "Is the heart beating?", "How well is it beating?" and "Is there an immediately treatable, reversible cause?". Identifying the reversible causes of PEA can help guide resuscitation and influence treatment and transport decisions.

The future direction and treatment of PEA recognition prehospital needs to be further investigated. The study seeks to establish whether it is possible for paramedics to differentiate between true and pseudo-PEA without interruption to the 10-second pulse check pause. If they can, then paramedics have the potential to correct a further four reversible causes of PEA cardiac arrest and detect low flow shocked states. The anticipated benefit is that the survival rate among patients in PEA could increase if pseudo-PEA cases are recognised and treated appropriately. Results from this study may inform decisions on the use of ultrasound in PEA cardiac arrest within the ambulance service. In addition, the findings of this research may be used for academic publications and presentations.

How was I identified and why am I being invited to participate in this research?

You have been identified as an employee of WFA with an ATP of Paramedic level or above. You are eligible to be included in the study if you meet the five following criteria:

- ☐ Paramedic level or above
- ☐ Paramedic registration
- ☐ Working in a frontline clinical capacity
- ☐ Current Annual Practising Certificate
- ☐ Bachelor of Health Science in Paramedicine or equivalent qualification

Please note that you cannot participate in the study if you have previous clinical ultrasound experience.

How do I agree to participate in this research?

Your participation in this research is voluntary (it is your choice), and whether or not you choose to participate will neither advantage nor disadvantage you. You are able to withdraw from the study at any time. If you choose to withdraw from the study, then you will be offered the choice between having any data that is identifiable as belonging to you removed or allowing it to continue to be used. However, once the findings have been produced, removal of your data may not be possible.

If you agree to take part in this study, you will be asked to sign the Consent Forms at the end of this document. You will be given a copy of both the Participant Information Sheet and the Consent Forms to keep.

This document is five pages long, including the Consent Forms. Please make sure you have read and understood all pages.

What will happen in this research?

There are three phases to the CAFÉ research trial. As a participant, you will be asked to participate in all three phases of the study. You will be asked to learn the basics of echo ultrasound, safety, cultural awareness, and cardiac arrest ultrasound integration.

The phases will occur over three months, with each phase occurring every 3-4weeks. Phases II and III are held at the Wellington Hospital Simulation Suite.

Phase I is a 2-hour online educational component. You will learn the theoretical and practical elements of focused echocardiography (echo) and how to integrate the CAFÉ exam into the pulse check pauses at simulated cardiac arrests. The application of ultrasound during the resuscitation is supernumerary (extra) and will not interrupt or influence the flow of the cardiac arrest.

Phase II is a 6-hour didactic hands-on training course. You will have the opportunity to scan healthy volunteers. This time supports your learning and ultrasound skills. The end of Phase II will assess your knowledge and abilities through testing and simulation. Participants are required to achieve at least 90% to pass this assessment and progress to Phase III. However, if you do not pass this assessment, further training will be offered to help you pass.

Phase III is a 1-hour assessment. The Phase III assessments are a knowledge test (conducted onsite and online), a practical echo skills assessment and simulation that integrates the CAFÉ exam.

What are the discomforts and risks?

You may feel uncomfortable with simulation and assessments. Our intention is to provide a safe, friendly, supportive learning environment. You should be able to enjoy a stress-free research experience.

How will these discomforts and risks be alleviated?

To reduce the discomfort of being assessed, we will ensure that all assessments are private using separate rooms or screens. Your assessment results are aligned with your study identification number and will remain confidential to the research team.

What are the benefits?

This is an opportunity for you to develop ultrasound knowledge and experience and participate in paramedic-led research. You may be able to claim up to nine CPD hours from the training module as professional development to demonstrate continuing education as part of your annual practising certificate renewal.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury resulting from your participation in this study, rehabilitation, and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

How will my privacy be protected?

We take privacy and confidentiality seriously. Your identity will be made anonymous after you commence Phase I. You will be issued a study code that will be matched with your results (data). This is to ensure anonymity between researcher and participant. Assessments and testing stations will use screens or separate rooms to maintain confidentiality and uphold research integrity. A pass mark of ≥ 90% is required to progress from phase II to III. If you do not pass phase II, you will be notified in confidence by an administrator and asked if you would like further training to help you achieve a pass mark. This will be commenced at a date that suits both participant and assessor within a period of three weeks following phase II. The lead researcher is not involved with this process to remained blinded.

What are the costs of participating in this research?

You will receive $20 koha per phase attended towards travel and parking. Food and drink will be provided during the Phase II training day. If you require a special diet, please email the study email provided. The total amount of your time is 9-hours, not including commute time for phases II and III.

What opportunity do I have to consider this invitation?

This invitation needs to be accepted or declined by 12th December 2021. During this time, you are most welcome to discuss with colleagues or contact the lead researcher Hannah Latta for further clarification.

Will I receive feedback on the results of this research?

At the completion of your assessments your assessor will provide you with immediate feedback. At the conclusion of the research, you will be provided with a summary of findings.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, *Dr Bronwyn Tunnage, Bronwyn.tunnage@aut.ac.nz,* (+649) 921 9999 ext 7088.

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, *ethics@aut.ac.nz* , (+649) 921 9999 ext 6038.

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Conflicts of Interest and Disclosure

The lead researcher (Hannah Latta) is employed by Wellington Free Ambulance as an Intensive Care Paramedic working as an ambulance officer. Hannah has no conflicts of interest and receives no financial benefit from representative companies. Specialist equipment for education and simulation is provided by Laerdal and Sonosim New Zealand for phases II and III of the trial. Ultrasound devices (Lumify) are provided by Philips for phases II and III of the trial.

Researcher Contact Details:

Hannah Latta, Hannah.latta@aut.ac.nz, (+649) 921 9999 ext. 7088.

Project Supervisor Contact Details:

Dr Bronwyn Tunnage, Bronwyn.tunnage@aut.ac.nz, (+649) 921 9999 ext. 7088.

Approved by the Auckland University of Technology Ethics Committee on *type the date final ethics approval was granted*, AUTEC Reference number *type the reference number.*

Consent Form

Who: ***Participant***

Project title: ***Integration of paramedic-led echocardiography in pulseless electrical activity (PEA) and out of hospital cardiac arrest: And education and simulation study.***

Project Supervisor: ***Dr Bronwyn Tunnage***

Researcher: ***Hannah Latta***

- O I have read and understood the information provided about this research project in the Information Sheet dated dd mm yyyy.
- O I have had an opportunity to ask questions and to have them answered.
- O I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.
- O I understand that if I withdraw from the study then I will be offered the choice between having any data or tissue that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.
- O I am not suffering from any illness or injury that impairs my physical performance requirements for your research.
- O I agree to provide my time to undertake this research.
- O I agree to take part in all three phases of this research.
- O I wish to receive a summary of the research findings (please tick one): Yes O No O

Participants Signature : .....

Participants Name : .....

Participants Contact Details

.....

.....

.....

.....

Date :

Approved by the Auckland University of Technology Ethics Committee on 30th of November 2021, AUTEC Reference number 21/327.

Volunteer Information Sheet

Date Information Sheet Produced: 27 August 2021

Project Title

Integration of paramedic-led echocardiography in pulseless electrical activity (PEA) at out-of-hospital cardiac arrests: An education and simulation study.

Project Identifier

The study is called the "Cardiac Arrest Focused Echo" (CAFÉ) exam.



An Invitation

My name is Hannah Latta. I am an intensive care flight paramedic and doctoral student at the Auckland University of Technology. I would like to invite you to participate in my research project. Volunteers are being sought from Wellington Free Ambulance (WFA) to act as models for ultrasound education and actors for cardiac arrest simulation.

What is the purpose of this research?

In a PEA cardiac arrest, the patient has no palpable pulse. The electrical impulse that stimulates the heartbeat is present, but the heart muscle does not respond. Research reveals that up to 75% of Out-of-Hospital Cardiac Arrest (OHCA) patients in PEA are found to have a heartbeat when examined with an ultrasound scan. However, the heartbeat in this pseudo-PEA state is too weak to generate a palpable pulse and instead of resuscitation being attempted, the patient may be declared dead.

A paramedic-led ultrasound scan of the heart during PEA allows the user to see a real-time image. This image answers the focused clinical questions of "Is the heart beating?", "How well is it beating?" and "Is there an immediately treatable, reversible cause?". Identifying the reversible causes of PEA can help guide resuscitation and influence treatment and transport decisions.

The future direction and treatment of PEA recognition prehospital needs to be further investigated. The study seeks to establish whether it is possible for paramedics to differentiate between true and pseudo-PEA without interruption to the 10-second pulse check pause. If they can, then paramedics have the potential to correct a further four reversible causes of PEA cardiac arrest and detect low flow shocked states. The anticipated benefit is that the survival rate among patients in PEA could increase if pseudo-PEA cases are recognised and treated appropriately. Results from this study may inform decisions on the use of ultrasound in PEA cardiac arrest within the ambulance service. In addition, the findings of this research may be used for academic publications and presentations.

How was I identified and why am I being invited to participate in this research?

You have been identified as an employee of WFA. Therefore, you are eligible to be a volunteer if you meet the following criteria:

- ☐ WFA employee
- ☐ Hold an EMT qualification or above

You cannot participate if you a) do not want to be scanned or b) part of a simulation team.

How do I agree to participate in this research?

Your participation in this research is voluntary (it is your choice), and whether or not you choose to participate will neither advantage nor disadvantage you. You are able to withdraw from the study at any time. If you agree to participate in this study, you will be asked to sign the Consent Forms at the end of this document. You will be given a copy of both the Volunteer Information Sheet and the Consent Forms to keep. This document is five pages long, including the Consent Forms. Please make sure you have read and understood all pages.

What will happen in this research?

There are three Phases. You will be involved in Phases II and III.

Phase II training day (live scanning): There are two 60-minute scanning sessions throughout the day, and paramedics will take turns using the ultrasound machine to look at your heart. You will be lying face-up on a bed. The two regions they will examine are the left front of the chest (parasternal) and under your breastbone (subcostal). There will be an instructor at the bedside to ensure your comfort and teach the paramedics how to perform an ultrasound. At the end of the day, the study participants will be tested, and we will need you to participate in simulations.

Phase II and III Simulation: We require volunteers to act as ambulance officers for cardiac arrest simulation stations. Each station requires three officers to perform the simulation whilst the study participant acts in a 'supernumerary' capacity, performing ultrasound during the pulse check pause in a non-shockable rhythm.

Privacy: Your privacy will be maintained using screens and appropriately placed sheets and towels. You will be asked to wear loose and comfortable clothing. Females are to wear a sports bra or crop top. Men will need to be shirtless. There will be limited contact between the study participants hand holding the ultrasound probe and the front of the chest and top of the abdomen. However, females, your breast will always remain covered by the sports bra.

Study location: Wellington Hospital Simulation suite.

What are the discomforts and risks and how will these be alleviated?

Ultrasound is completely safe and free of radiation. However, the constant pressure of an ultrasound probe on your chest makes you feel a little sore. Let your station doctor know if scanning is too painful. Occasionally, we find incidental abnormalities during the scan. If this is the case, we will notify you and guide you to the appropriate follow-up if needed.

What are the benefits?

This research is an opportunity for you to develop ultrasound knowledge. In addition, you may be able to claim CPD hours as professional development to demonstrate continuing education.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury resulting from your participation in this study, rehabilitation, and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

How will my privacy be protected?

We take privacy and confidentiality seriously. As a volunteer, you are covered under the rights of the volunteer, the Human Rights Act and Privacy Act of 2020 and the Health & Safety at Work Act 2015. At no stage should you feel uncomfortable or that your privacy is in question.

What are the costs of participating in this research?

You will receive $20 koha per phase attended towards travel and parking. In addition, food and drink will be provided for you. If you require a special diet, please email the study email provided. The total amount of your time is nine hours, not including commute time.

Conflicts of Interest and Disclosure

The lead researcher (Hannah Latta) is employed by Wellington Free Ambulance as an Intensive Care Paramedic working as an ambulance officer. Hannah has no conflicts of interest and receives no financial benefit from representative companies. Specialist equipment for education and simulation is provided by Laerdal and Sonosim New Zealand for phases II and III of the trial. Ultrasound devices (Lumify) are provided by Philips for phases II and III of the trial.

What opportunity do I have to consider this invitation?

This invitation needs to be accepted or declined by 12th December 2021. During this time, you are most welcome to discuss with colleagues or contact the lead researcher Hannah Latta for further clarification.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, *Dr Bronwyn Tunnage, Bronwyn.tunnage@aut.ac.nz,* (+649) 921 9999 ext 7088.

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, *ethics@aut.ac.nz* , (+649) 921 9999 ext 6038.

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details: Hannah Latta, Hannah.latta@aut.ac.nz, (+649) 921 9999 ext 7088.

Project Supervisor Contact Details: Dr Bronwyn Tunnage, Bronwyn.tunnage@aut.ac.nz, (+649) 921 9999 ext 7088.

Approved by the Auckland University of Technology Ethics Committee on *type the date final ethics approval was granted*, AUTEC Reference number *type the reference number.*

Consent Form

Who: ***Healthy Volunteer***

Project title: ***Integration of paramedic-led echocardiography in pulseless electrical activity (PEA) and out of hospital cardiac arrest: And education and simulation study.***

Project Supervisor: ***Dr Bronwyn Tunnage***

Researcher: ***Hannah Latta***

- O I have read and understood the information provided about this research project in the Information Sheet dated dd mm yyyy.
- O I have had an opportunity to ask questions and to have them answered.
- O I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.
- O I understand that if I withdraw from the study then I will be offered the choice between having any data or tissue that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.
- O I am not suffering from any illness or injury that impairs my physical performance requirements for your research.
- O I agree to being an ultrasound model, for research participants perform echo ultrasound. Yes O No O

AND / OR

- O I agree to participate as a role-playing paramedic for cardiac arrest simulations. Yes O No O
- O I agree to my ultrasound images (without identifying details) being stored and reviewed as part of this research project. Yes O No O
- O I wish to receive a summary of the research findings (please tick one): Yes O No O

Participants Signature : .....

Participants Name : .....

Participants Contact Details

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.....

.....

Date:

Approved by the Auckland University of Technology Ethics Committee on 30th of November 2021, AUTEC Reference number 21/327.

Assessors Information Sheet

Date Information Sheet Produced: 27 August 2021

Project Title

Integration of paramedic-led echocardiography in pulseless electrical activity (PEA) at out-of-hospital cardiac arrests: An education and simulation study.

Project Identifier

The study is called the "Cardiac Arrest Focused Echo" (CAFÉ) exam.



An Invitation

My name is Hannah Latta. I am an intensive care flight paramedic and doctoral student at the Auckland University of Technology. I would like to invite you to participate in my research project. Ultrasound qualified assessors are being sought to assist with practical ultrasound education and assessments.

What is the purpose of this research?

In a PEA cardiac arrest, the patient has no palpable pulse. The electrical impulse that stimulates the heartbeat is present, but the heart muscle does not respond. Research reveals that up to 75% of Out-of-Hospital Cardiac Arrest (OHCA) patients in PEA are found to have a heartbeat when examined with an ultrasound scan. However, the heartbeat in this pseudo-PEA state is too weak to generate a palpable pulse and instead of resuscitation being attempted, the patient may be declared dead.

A paramedic-led ultrasound scan of the heart during PEA allows the user to see a real-time image. This image answers the focused clinical questions of "Is the heart beating?", "How well is it beating?" and "Is there an immediately treatable, reversible cause?". Identifying the reversible causes of PEA can help guide resuscitation and influence treatment and transport decisions.

The future direction and treatment of PEA recognition prehospital needs to be further investigated. The study seeks to establish whether it is possible for paramedics to differentiate between true and pseudo-PEA without interruption to the 10-second pulse check pause. If they can, then paramedics have the potential to correct a further four reversible causes of PEA cardiac arrest and detect low flow shocked states. The anticipated benefit is that the survival rate among patients in PEA could increase if pseudo-PEA cases are recognised and treated appropriately. Results from this study may inform decisions on the use of ultrasound in PEA cardiac arrest within the ambulance service. In addition, the findings of this research may be used for academic publications and presentations.

How was I identified and why am I being invited to participate in this research?

You have been identified as a doctor and employee of CCDHB. Therefore, you are eligible to be a volunteer if you meet the following criteria:

- ☐ CCDHB employee
- ☐ ASUM CCHPU accredited
- ☐ In Wellington February – March 2022

How do I agree to participate in this research?

Your participation in this research is voluntary (it is your choice), and whether or not you choose to participate will neither advantage nor disadvantage you. You are able to withdraw from the study at any time. If you agree to participate in this study, you will be asked to sign the Consent Forms at the end of this document. You will be given a copy of both the Assessors Information Sheet and the Consent Forms to keep. This document is four pages long, including the Consent Forms. Please make sure you have read and understood all pages.

What will happen in this research?

There are three Phases. You will be involved in Phases II and III.

Phase I is an online education module there is no requirement of you for this module.

Phase II is a 6-hour didactic hands-on training course. There are two 60-minute scanning sessions throughout the day, and paramedics will take turns using the ultrasound machine to perform echocardiography. This will be the first time the paramedics have used ultrasound. You will be asked to supervise a scanning station, provide assistance and education with echo image acquisition and transducer manipulation. Scanning is performed on healthy volunteers who will be under your direction. At the end of the training day, paramedics will be assessed on these skills through simulation. Your total time commitment for Phase III is 5 hours including lunch and afternoon tea breaks.

Phase III is a 1-hour assessment. The Phase III assessments are a knowledge test (conducted onsite and online), a practical echo skills assessment and two cardiac arrest simulation that integrates the CAFÉ exam.

Simulation: You will be asked to assess paramedics ability to acquire and interpret an ultrasound scan of the heart. Each paramedic (30 total) will be assessed once per station. During the simulation, which will be role-played by WFA staff, the study paramedic will act in a 'supernumerary' capacity, performing ultrasound during the pulse check pause in a non-shockable rhythm. Your total time commitment for Phase III is 5 hours including lunch and afternoon tea breaks.

What are the discomforts and risks and how will these be alleviated?

There is no risk to you however management of fatigue and work-life balance is important, and we would like to ensure you are rested before your next scheduled work shift.

What are the benefits?

This research is an opportunity for you share your knowledge and experience to paramedics. In addition, you may be able to claim CPD hours as professional development.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury resulting from your participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

How will my privacy be protected?

We take privacy and confidentiality seriously. As a volunteer, you are covered under the rights of the volunteer, the Human Rights Act and Privacy Act of 2020 and the Health & Safety at Work Act 2015. At no stage should you feel uncomfortable or that your privacy is in question.

What are the costs of participating in this research?

You will receive koha towards travel and parking. In addition, food and drink will be provided for you. If you require a special diet, please email the study email provided. The total amount of your time is nine hours, not including commute time. However, this may be shared between assessors to reduce your time burden.

Conflicts of Interest and Disclosure

The lead researcher (Hannah Latta) is employed by Wellington Free Ambulance as an Intensive Care Paramedic working as an ambulance officer. Hannah has no conflicts of interest and receives no financial benefit from representative companies. Specialist equipment for education and simulation is provided by Laerdal and Sonosim New Zealand for phases II and III of the trial. Ultrasound devices (Lumify) are provided by Philips for phases II and III of the trial.

What opportunity do I have to consider this invitation?

This invitation needs to be accepted or declined by 12th December 2021. During this time, you are most welcome to discuss with colleagues or contact the lead researcher Hannah Latta for further clarification.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, *Dr Bronwyn Tunnage, Bronwyn.tunnage@aut.ac.nz,* (+649) 921 9999 ext 7088.

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, *ethics@aut.ac.nz* , (+649) 921 9999 ext 6038.

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details: Hannah Latta, Hannah.latta@aut.ac.nz, (+649) 921 9999 ext 7088.

Project Supervisor Contact Details: Dr Bronwyn Tunnage, Bronwyn.tunnage@aut.ac.nz, (+649) 921 9999 ext 7088.

Approved by the Auckland University of Technology Ethics Committee on *type the date final ethics approval was granted*, AUTEC Reference number *type the reference number.*

Consent Form

Who: ***Ultrasound Mentor and Assessor***

Project title: ***Integration of paramedic-led echocardiography in pulseless electrical activity (PEA) and out of hospital cardiac arrest: And education and simulation study.***

Project Supervisor: ***Dr Bronwyn Tunnage***

Researcher: ***Hannah Latta***

- O I have read and understood the information provided about this research project in the Volunteer Information Sheet dated dd mm yyyy.
- O I have had an opportunity to ask questions and to have them answered.
- O I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.
- O I understand that if I withdraw from the study then I will be offered the choice between having any data or tissue that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.
- O I am not suffering from any illness or injury that impairs my physical performance requirements for your research.
- O I agree to assisting in the education and training of research participants. YesO NoO

AND / OR

- O I agree to assisting in the assessment of research participants. YesO NoO
- O I agree to volunteer my time to take part as a mentor in this research. YesO NoO

AND / OR

- O I agree to volunteer my time to take part as an assessor in this research. YesO NoO
- O I wish to receive a summary of the research findings (please tick one): YesO NoO

Participants Signature : .....

Participants Name : .....

Participants Contact Details

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.....

.....

Date:

Approved by the Auckland University of Technology Ethics Committee on 30th of November 2021, AUTEC Reference number 21/327

Appendix K

Research Budget 2022

Resources and Budget								
Item	Context	Amount	Cost pp	DHSc Funds	WFA Funds	HF Grant	Seed Funds	Total
Phase I	Nil	0	$ -					$ -
Study Identificatio	Participant name sticker	2	$15.00	$ 30.00				$ 30.00
	Particpant gift - labelled cup	50			$ 856.75			$ 856.75
Faculty	T-shirt polo	13		$ 361.00	$ 143.00			$ 504.00
Phase II (group A)	Participant petrol voucher	15	$20.00			$ 300.00		$ 300.00
	Volunteer petrol voucher	10	$20.00	$ 200.00				$ 200.00
	Doctors petrol voucher	5	$20.00	$ 100.00				$ 100.00
	Doctors Pay (gift koha - vouchers)	5	$50/hr				$ 1,000.00	$ 1,000.00
	Research staff	2						
	Food (Pita Pit) - Lunch	35	$10.00	$ 350.00				$ 350.00
	Snacks (healthy)	1		$ 85.00				$ 84.89
Phase II (group B)	Participant petrol voucher	15	$20.00			$ 300.00		$ 300.00
	Volunteer petrol voucher	10	$20.00	$ 200.00				$ 200.00
	Doctors petrol voucher	5	$20.00	$ 100.00				$ 100.00
	Doctors Pay (gift koha - vouchers)	5	$50/hr				$ 1,000.00	$ 1,000.00
	Research staff	2						
	Food (Pita Pit) - Lunch	35	$10.00	$ 350.00				$ 350.00
	Snacks (healthy)	1		$ 85.00				$ 84.89
Phase III (group A)	Participant petrol voucher	15	$20.00	$ 300.00				$ 300.00
	Volunteer petrol voucher	8	$20.00	$ 160.00				$ 160.00
	Assessors petrol voucher	4	$20.00	$ 80.00				$ 80.00
	Doctors Pay (gift koha - vouchers)	4	$50/hr				$ 800.00	$ 800.00
	Research staff	2						
	Food - Lunch	15	$10.00	$ 150.00				$ 150.00
	Snacks (healthy)	1		$ 30.00				$ 30.00
Phase III (group B)	Participant petrol voucher	15	$20.00			$ 300.00		$ 300.00
	Volunteer petrol voucher	8	$20.00	$ 160.00				$ 160.00
	Assessors petrol voucher	4	$20.00	$ 80.00				$ 80.00
	Doctors Pay (gift koha - vouchers)	4	$50/hr			$600	$200	$ 800.00
	Research staff	2						
	Food (Pita Pit) - Lunch	15	$10.00	$ 150.00				$ 150.00
	Snacks (healthy)	1		$ 30.00				$ 30.00
Total (Phase II and III)				$ 3,001.00	$ 999.75	$1,500.00	$ 3,000.00	$ 8,500.53
Amount funded potentially				$ 3,000.00	$ 1,000.00		$ 3,000.00	
Remaining unfunded				$ 1.00	$ -	$ -	$ -	$ 1.00

Note. WFA = Wellington Free Ambulance, HF Grant = Heart Foundation Grant.

Appendix L

Continuing Professional Development Certificate of Completion



Appendix M

CAFE Module One Document

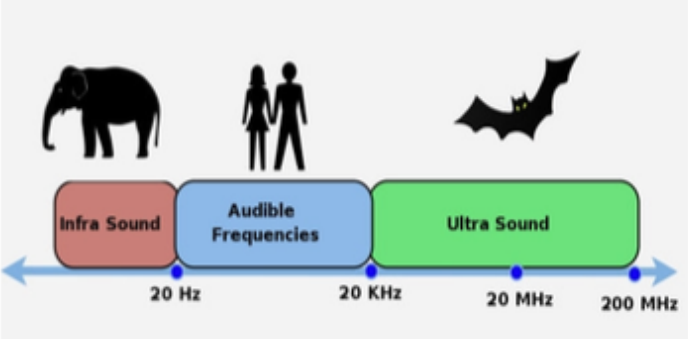
What is Ultrasound?

Ultrasound devices use high frequency sound waves to produce pictures of tissue mediums within the body. The high frequency ultrasound waves can only travel through a physical medium. This medium may consist of matter such as human tissue.

Ultrasound gel is an essential coupling agent to broach the air skin barrier boosting the sound wave. The gel becomes the physical medium broaching the air between probe and skin interface. It is important to use lots of gel.

Ultrasound vibrates at a frequency that is not audible by the human ear, greater than 20,000 Hertz (Hz). A Hertz is defined as one wave per second. Medical ultrasound typically sends out 2 – 15 million Hz per second. An example of sound range frequency is shown in Figure 2.

Figure 1.Frequency Range – Ultrasound



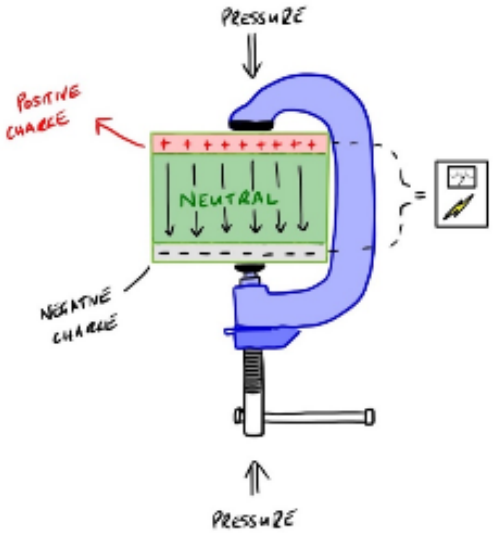
Source: http://www.msrblog.com/science/medical/ultrasound.html

Piezoelectricity

The Greek word *piezein* means to squeeze or press and *electron* means amber, an ancient source of electric charge. Certain solid materials such as crystals and ceramics when

mechanically stressed (squeezed, bent or twisted) have the ability to accumulate an electric charge called piezoelectricity. When placed under stress, the piezoelectric material polarizes proportional to the stressor. The image in Figure 3 demonstrates that when pressure is applied to a neutrally charged piezoelectric material (indicated by the green zone), the outer surfaces (red and grey) create a small voltage potential difference allowing the flow of current creating a voltage.

Figure 2. Piezoelectricity



Source: Image copyright to author.

The most commonly used material in ultrasound transducer sensors is Lead Zirconate Titrate (*PbZrxTi1xO3: PZT*). PZT crystals are an ideal substrate as they are physically strong, chemically inert and relatively inexpensive to manufacture. However, it is essential to please take care with ultrasound transducers. A simple drop to the ground could fracture a crystal or electrical coupling rendering the $3,000-20,000 transducer broken.

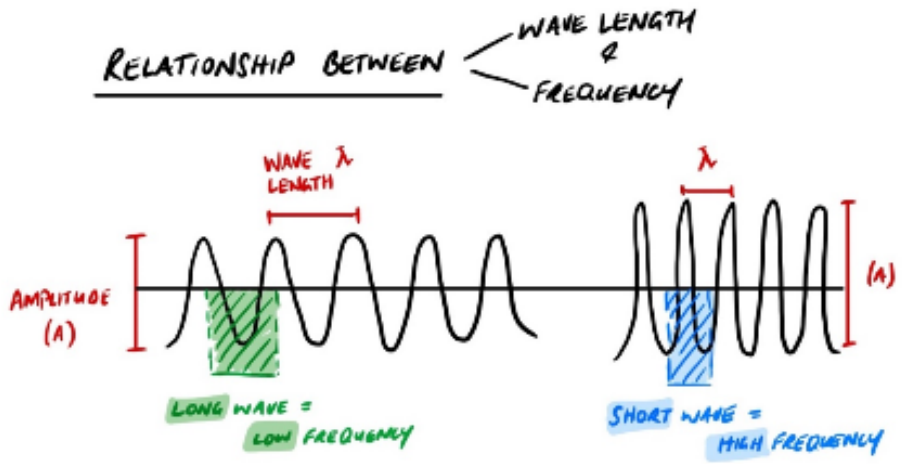
When an electrical current is applied to a piezoelectric crystal, it starts to vibrate, generating sound waves at frequencies between 1.5 and 8 megahertz (MHz) (sometimes higher frequencies in specialised transducers). Ultrasound devices act both as a sensor and actuator. An actuator is a component that is responsible for moving and controlling a mechanism or system. The actuator converts the electrical charge into vibration. The sensor (receiver)

converts the mechanical vibration into an electric signal. The piezoelectrical effect is reversable.

Sound Waves

In diagnostic ultrasound, sound waves (acoustic waves) pulse through a tissue (medium), reflecting off structures in the body. The sound waves then return to the transducer where they are processed into an image (Edelman, 2007). Whenever the transmitted pulse encounters a tissue structure, a fraction of its energy is scattered or reflected. This gives rise to *echoes* which can be detected by the transducer. The machine uses these echoes to create the ultrasound image. The mechanism behind this is due to the fact sound travels in a straight line and can carry energy from one location to another. Wavelength is less than 1 mm for diagnostic ultrasound frequencies and it decreases as the frequency increases. This is consistent with the statement above that the best resolution is achieved by using the highest possible frequency. Sound waves are classified as longitudinal waves, and the relationship between sound waves and frequency is detailed in Figure 4.

Figure 3. Sound Wave and Frequency Relationship



Source: Image copyright to author.

Transducer Technology

The majority of modern transducers contain multiple active elements called an array. An array is a single piece of PZT cut into separate pieces called elements. Each element is connected to a wire, which connects to a circuit board within the ultrasound system. The entire system (element, wire and electronics) is called a channel. This technology allows a single or group of elements to excite at one time (Edelman, 2007). Figure 6, graphically represents the basics of transducer technology.

Figure 4. Transducer Basics

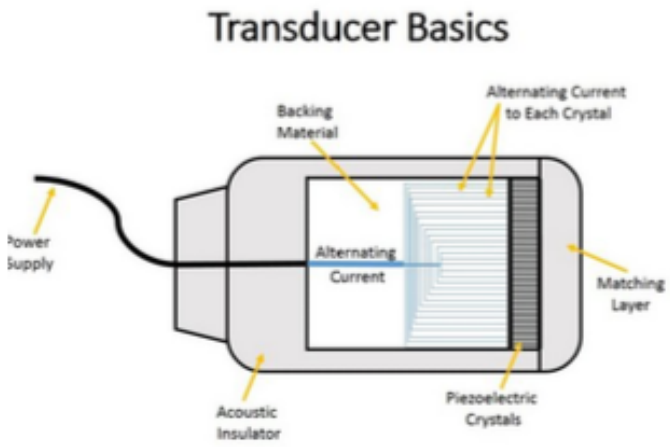


Image Source: https://www.vaultrasound.com/educational-resources/ultrasound-physics/transducers/

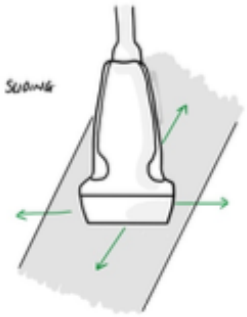
Phased Array Transducer (2-8MHz)



The phased array transducer has a compact footprint making it the ideal probe for echocardiography, especially when looking through the intercostal spaces. This low to medium range frequency transducer allows for higher tissue penetration and improved frame rate to capture moving structures. This transducer is used mainly for echocardiography, and has been nicknamed the "cardiac transducer".The field of view of this transducer is narrow, but can be compensated by moving around the chest to view all elements of the structure being scanned.

Transducer Movements

The four basic movements of the transducer include rotating, sliding, rocking and fanning.

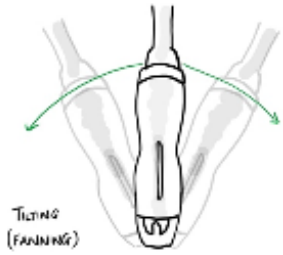


Sliding

Sliding involves moving the entire probe forwards/backwards and side to side to improve your imaging window. Sliding is best used to locate specific structures.

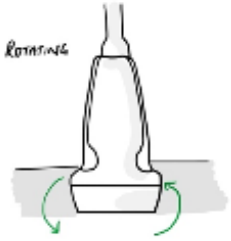
Fanning (Tilting)

Tilting or fanning the transducer allows the user to view a specific slice of the heart.



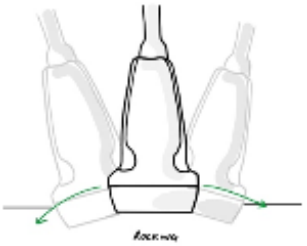
Rotating

Rotation of the ultrasound transducer involves twisting in a clock wise or counter clock wise motion around a central point. Rotation is commonly used to switch between long and short axis. This is commonly used when examining the heart.



Rocking

Rocking of the transducer involves rocking from side to side like a sea saw. Rocking helps to centre your point of interest by changing the angle of your ultrasound beam.



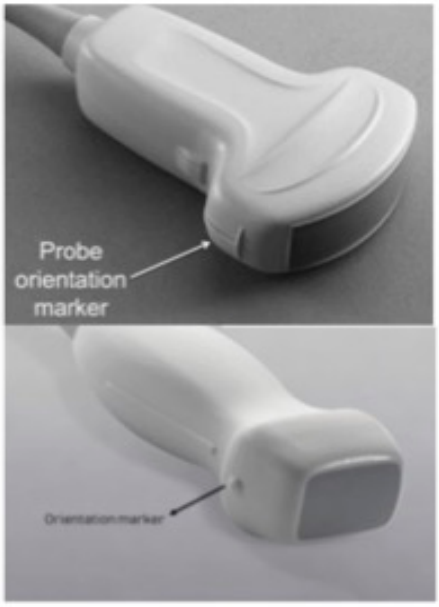
Appendix N

CAFE Module Two Document

Transducer Orientation

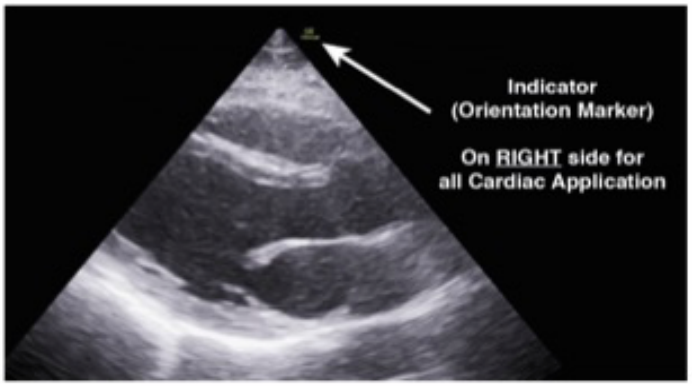
The orientation marker also called the notch or index marker. This marker corresponds to the screen orientation marker. Modern transducers typically have a tactile plastic ridge, divot or colour marking to indicate transducer orientation, shown in figure 1 and 2.

Figure 1. **Curvilinear Transducer**



Source: www.mmheme.org/knobology

Figure 2 Screen marker orientation echo image



Ultrasound Device Orientation

Starting Exams

Before starting an exam, connect a transducer to your device. The presets on the **Scan/Create Patient** display are transducer-dependent.

1. Connect a transducer to your device.
2. On the **Scan/Create Patient** display, touch an exam preset.
3. To create a temporary Quick ID and start scanning immediately, touch **Scan**.
4. To manually enter patient information before you begin scanning, touch **Create Patient**, enter the patient information, and then touch **Start Exam**.



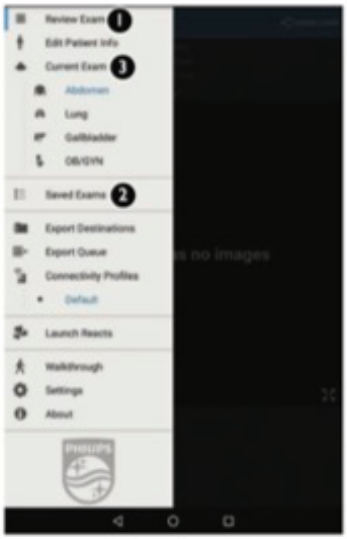
Reviewing Exams

To start or exit review:

1. To start Review during an exam, touch , and then touch **Review Exam** .
2. To start review after an exam is ended, touch , touch **Saved Exams** , and then select the exam to review.
3. To exit **Review** and return to the current exam, touch , and then touch **Current Exam** .

To view or delete images and loops:

1. To scroll through the thumbnails, drag the thumbnails left or right, or up or down, depending on the screen orientation.
2. To view a full-size image or loop, touch a thumbnail.
3. To delete an image or loop, touch and hold the thumbnail until **Done** appears in the upper left of the display. Touch **Delete** .



Focus Depth and Brightness

1. To change the distance from the face of the transducer to the deepest point on the image, use the **Depth** dial.
2. To adjust image brightness, use the **Gain** dial.

Zoom

1. To magnify an image, spread two fingers on the image.
2. To pan the magnified image, drag with one finger.
3. To decrease the magnification, pinch two fingers together on the image.

NOTE
If you spread or pinch inside a color box, you resize the color box instead of zooming.



Ultrasound Terminology Definitions

Hyperechoic (bright white)

Returning sound waves with increased amplitude appear brighter than the surrounding tissue.

Hypoechoic (darker grey)

Returning sound waves with decreased amplitude appear darker than the surrounding tissue.

Isoechoic (similar)

Returning sound waves are of similar amplitude and appear equal on the grey scale. For example, the spleen and kidneys are isoechoic or of similar grey scale.

Echogenic

Echogenic refers to how bright or dark and object appears within the grey-scale image. Echogenicity is the ability to bounce and echo.

Anechoic (black)

There is a complete absence of returning sound waves resulting in a black appearance. Examples of fluid that appear anechoic include; un-clotted or fresh blood, urine, transudative pleural effusions, ascites and simple cysts.

Gain (brightness/darkness)

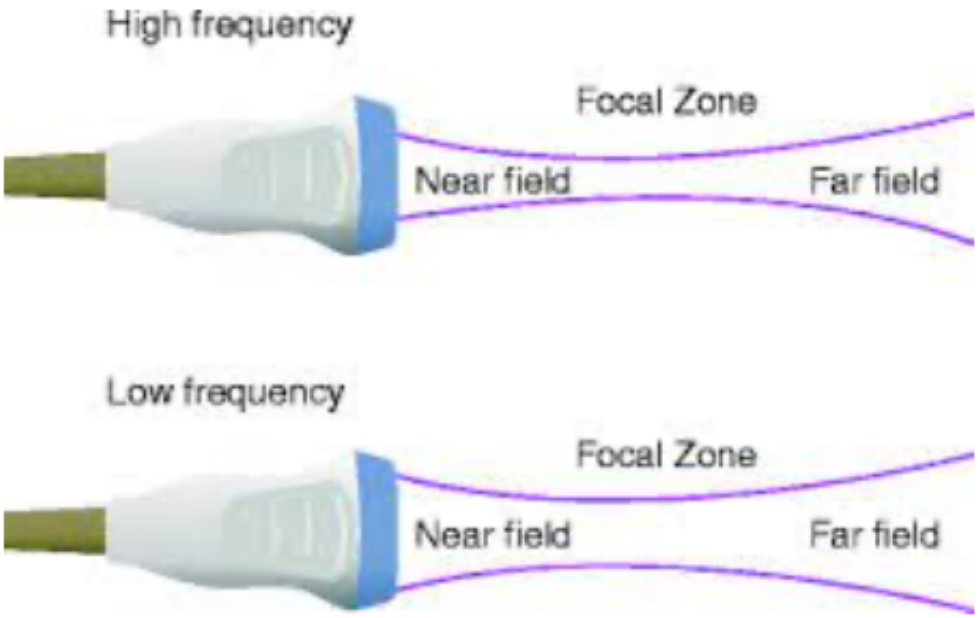
Receiver gain (also called amplification) alters the strength of the voltages in the ultrasound receiver after reception by the transducer. The higher the amplification the brighter the

image and the darker the image the lower the amplification. There is no noise distortion using this setting as they are both meaningful signals. Gain is something that can be adjusted, if you do this, be careful to not over or under gain your image.

Depth

Depth of field, like in a photograph is important, no one wants to look at a fuzzy image. As an example, to create an ultrasound image that is 10 cm deep requires >90 individual ultrasound pulses in slightly more than 1/100th of a second. In other words that's heaps of photos over a super short period of time. Impressive! Combined with depth is focal zone. Figure 3 shows the narrowing of the ultrasound beam at the focal zone. This is the area of most focus (image sharpness and detail). Best practice is to place your area of interest in the focal zone. You can do this by adjusting your depth so your focal zone is in the middle of your image. Images that fall outside of the focal zone are less defined and pathology may be missed.

Figure 3 Focal Zone



Source: https://www.cambridge.org/core/books/abs/ultrasoundguided-regional-anesthesia/introduction-to-ultrasound/D1B631E50698D6956194B69408075DA6

Appendix O

Simulation Assessment Form Phase II

CAFÉ Competence Assessment From (Phase II)

Simulation 1 – 15mins (10mins sim + 5mins debrief)

Study Participant ID number : _____

Assessor: _____

(Assessor to read the following scenario):
You attend a 45-year old male who has suddenly collapsed whilst playing squash. The crew on scene have called R49. You arrive and perform an ultrasound at the next rhythm check. The patient is in a PEA rhythm has IV insitu, the ICP has intubated and the arrest is being run well. The total patient down-time is 12-mins with no-shocks delivered. Please enter the scene and demonstrate the CAFE exam integration.

		C	NYC				
Equipment	Transducer (cardiac)						
	Echo setting selected						
	Gel on transducer						
Data Entry	Enters student ID/station details *(for example: stu123Sim1)*						
Rhythm	Confirms PEA on defib monitor						
		Scan 1		Scan 2		Scan 3	
CAFE Exam		C	NYC	C	NYC	C	NYC
	Pre-imaging during CPR *(end of cycle)*						
	CPR officer stops *(Officer hovers hands above chest ready to recommence CPR unless using PLAX view)*						
	Press record when CPR stops						
	Actual scan time (in seconds)						
Image Review ***(**Substitute scan)***	Reviews substitute scan during CPR cycle						
	Fluid assessment correct? (patho scan)	Retrospective review – for completion later					
	Function assessment correct? (patho scan)						
Live Scan	Depth correct?						
	Axis Adequate?						
	Gain optimal?						

****Assessor to show the study participant a substitute scan during:**

1. **Pre-imaging – CPR subcostal scan**
2. **Image review (during CPR cycle) - substitute pathological scan in place of the live scan.**

Circle: Competent / Not yet competent

Assessor Feedback:

Assessor Signature: _____

Simulation Assessment Form Phase III

CAFÉ Competence Assessment From (Phase III)

Simulation 2 – 15mins (10mins sim + 5mins debrief)

Study Participant ID number : _____

Assessor: _____

(Assessor to read the following scenario):
You attend a 66-year-old European female who has collapsed at home after being discharged from the hospital two days ago following triple coronary bypass surgery. The crew on scene have called R49 (cardiac arrest. You arrive and perform an ultrasound at the next rhythm check. The patient is in a PEA rhythm has IV's insitu, the ICP has intubated and the arrest is being run well. The total patient down-time is 14-mins with no-shock advised. The fire department are in attendance performing CPR. Please enter the scene and demonstrate the CAFE exam integration.

		C	NYC				
Equipment	Transducer (cardiac)						
	Echo setting selected						
	Gel on transducer						
Data Entry	Enters student ID/station details *(for example: stu123Sim1)*						
Rhythm	Confirms PEA on defib monitor						
		Scan 1		Scan 2		Scan 3	
		C	NYC	C	NYC	C	NYC
CAFE Exam	Pre-imaging during CPR *(end of cycle)*						
	CPR officer stops *(Officer hovers hands above chest ready to recommence CPR unless using PLAX view)*						
	Press record when CPR stops						
	Hands off time in sec						
Image Review *(**Substitute scan)*	Reviews substitute scan during CPR cycle						
	Fluid assessment correct? (patho scan)	Retrospective review – for completion later					
	Function assessment correct? (patho scan)						
Live Scan	Depth correct?						
	Axis Adequate?						
	Gain optimal?						

1

**Assessor to show the study participant the pre-determined cardiac arrest pathological scan in place of the live scan for image review.

Circle: Competent / Not yet competent

Assessor Feedback:

Assessor Signature: _____

Appendix P

Echo Assessment Form

Echo Competence Assessment From (Phase III)

Duration: 5-minutes

Study Participant ID number: _____

Assessor: _____

Assess image acquisition of the subcostal, parasternal long axis and apical four chamber views.

		Competent	Not yet competent
Equipment	Transducer (cardiac)		
	Setting (cardiac)		
	Ultrasound gel		
Data entry	Enters student ID/station details *(for example: stu123Echo2)*		
Subcostal	Probe orientation marker (L) hip)		
	Image centre		
	Correct depth		
Identifies Anatomy	Right ventricle		
	Mitral or tricuspid valve		
	Pericardium		

PLAX	Probe orientation marker (R) shoulder)		
	Image centre		
	Correct depth (descending aorta in view)		
Identifies Anatomy	Left ventricle		
	Right ventricle		

Apical	Probe orientation marker (L) axilla)		
	Image centre		
Identifies Anatomy	Left ventricle		
	Pericardium		

Assessor Signature: _____

Appendix Q

Photos of Wellington and Tawa Research Days



Appendix R

Confidentiality Agreement External Reviewers – Template



Confidentiality Agreement

Project title: Integration of paramedic-led echocardiography in pulseless electrical activity (PEA) at out-of-hospital cardiac arrests: An education and simulation study.

Research Supervisors: Dr Bronwyn Tunnage and Dr Andy Swain

Research External Advisor: Dr Scott Bomann

Lead Researcher: Hannah Latta

- ○ I understand that the contents of the information provided including study participant ultrasound video images or hard copy material can only be discussed with the researchers involved with this research.
- ○ I will not keep any copies of the information nor allow third parties access to them.

External Reviewer Signature : .....

External Reviewer Name : .....

External Reviewer Contact Details and Credentials :

.....

.....

.....

.....

Date:

Approved by the Auckland University of Technology Ethics Committee on 30th November 2021 AUTEC Reference number 21/327

Note: The External Reviewer should retain a copy of this form.

Appendix S

ASUM Conference Abstract Submission

CERTIFICATE IN PARAMEDIC PERFORMED ULTRASOUND PROPOSAL 2022

Certificate in Paramedic Performed Ultrasound (CPPU)

Purpose

To introduce an ASUM Certificate in Paramedic Performed Ultrasound (CPPU) to align with paramedic practice requirements. This process involves merging existing modules from CAHPU and CCPU to form the new CPPU pathways. Modules can be tailored to both extended care paramedicine and critical care paramedicine.

Introduction

Point-of-care Ultrasound (POCUS) has rapidly evolved and has been adopted by many medical specialties including paramedicine. There are significant benefits to POCUS use prehospital in both diagnostic and intervention imaging. Diagnostic imaging is used to support and contribute to information relating to physical examination and diagnosis. Intervention imaging is used to guide interventional procedures such as peripheral intravenous cannulation and fascia iliaca block. The enhanced technology enables prehospital professionals to answer focused clinical questions, which translates into faster and more accurate diagnosis and care of patients presenting with time-sensitive pathology. Better outcomes have been reported with the use of prehospital ultrasound. However, comprehensive POCUS frameworks are essential to ensure the highest standards of clinical quality and safety. A CPPU specific to the paramedic scope is needed to progress the safe implementation and continued practice of ultrasound prehospital.

Benefits of Ultrasound Prehospital

The goal of ultrasound is to improve the diagnostic ability facilitating improved clinical management, early recognition of surgical emergencies and appropriate destination decisions for trauma and medical patients. The perceived shortfalls of ultrasound may include paramedic sonographer experience, interpretation error, distraction, and increased scene time. Delays should only occur when ultrasound is deemed part of the resuscitative process, for example: performing a lung ultrasound prior to finger thoracostomy which is deemed clinically appropriate. To reduce delays scanning can be conducted during other interventions or transport, and should not delay time to definitive care. These shortfalls can

be managed using the five pillars of POCUS; governance, infrastructure, administration, education and quality.

Auckland University of Technology

I have developed and led the Auckland University of Technology (AUT) paramedic ultrasound 15-point RADY801 course. This course is designed to provide safe and competent prehospital ultrasound practitioners. Postgraduate students participate in 12 weeks of online theoretical learning using a variety of interactive media and a two-day comprehensive block course. A summary of the course content is shown in Table 1.

Table 1. RADY801 Course Content

Week 1	Ultrasound Physics and safety
Week 2	Ultrasound Transducers and Artifacts of Ultrasound
Week 3	Respiratory Ultrasound
Week 4	Echocardiography 1
Week 5	Echocardiography 2
Week 6	Abdominal Ultrasound 1
Week 7	Abdominal Ultrasound 2
Week 8	Trauma and Undifferentiated Shock
Week 9	Procedural Guided Ultrasound
Week 10	Community Care and Cardiac Arrest Integration
Week 11	Critical Care Paramedic Ultrasound Application Extensions
Week 12	Brining it all together – Consolidation of ultrasound learning

Students are required to submit two essays, 1: Physics of Ultrasound (2000 words) and 2: A case study analysis pertaining to their clinical practice (3000 words). Students are also required to attend three online lectures of which there are six in total.

RADY801 Learning Outcomes

Week 1: Physics

1. Understand the principles of ultrasound in the critical care environment.
2. Define the primary goals of ultrasound prehospital.
3. Demonstrate knowledge of the piezoelectricity.
4. Demonstrate a basic knowledge of ultrasound physics.
5. Know the frequencies of medical ultrasound, image quality and penetration.
6. The basic components of an ultrasound machine.

7. Knowledge of ultrasound imaging planes and the relationship to ultrasound.
8. Transducer movements and axis orientation.

Week 2: Transducers and Ultrasound Artifacts

1. Understand the rationale for transducer and screen orientation.
2. Knowledge of ultrasound terminology.
3. Knowledge of medical ultrasound artifacts.
4. Basic knowledge of ultrasound device functions and modes.
5. Describe the ALARA principle.

Week 3: Respiratory Ultrasound

1. Clinical roles of lung ultrasound.
2. Clinical context and limitations of lung ultrasound in the out of hospital setting.
3. Describe the technique for lung scanning using ultrasound.
4. Understand transducer choice and how this effects the assessment of the pleural line.
5. Knowledge of lung ultrasound terminology and image optimisation.
6. Describe: the normal surface anatomy and artifacts of lung ultrasound.
7. Describe: the sonographic findings of common out-of-hospital pathology: pleural effusions, pneumothorax, pulmonary oedema, pulmonary consolidation.

Week 4: Echocardiography 1

1. Develop an understanding of the principles of echo ultrasound.
2. Describe the indications for the use of ultrasound in assessing the heart prehospital.
3. Understand transducer choice and how this effects image quality.
4. Develop a working knowledge of the heart anatomy and cardiac cycle.
5. Develop a working knowledge of the views used in echo ultrasound and how to acquire them.
6. Describe the sonographic anatomy of the heart.

Week 5: Echocardiography 2

1. Identify and discuss: the IVC ratio, sonographic signs of PE, hypovolemia, regional wall abnormalities and right heart strain.
2. The learner will have a theoretical knowledge of how to obtain echocardiography views and evaluate images using the four E's of echo.
3. The learner will develop methods for evaluating left ventricular function
4. The learner will begin to recognise echocardiographic views and have knowledge of how to improve an image quality.
5. The learner will begin to identify sonographic echo pathology.
6. The learner will develop a working knowledge of the limitations of ultrasound within the clinical context.

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Week 6: Abdominal Ultrasound 1

1. Develop an understanding of the basic abdominal views and frequently presenting pathology.
2. Describe the sonographic signs of abdominal pathology.
3. Develop theoretical knowledge of how to obtain abdominal views and evaluate images in both transverse and sagittal views.
4. Recognise abdominal views and have the knowledge of how to improve image quality and optimise depth.
5. Develop a working knowledge of the limitations of abdominal ultrasound within the clinical context.

Week 7: Abdominal Ultrasound 2

1. Build on current knowledge of the basic abdominal views and commonly presenting pathology.
2. Understands the indications for abdominal ultrasound.
3. Describe the left upper quadrant and the basics of ultrasound in this area.
4. Define the three types of abdominal aortic aneurysm and describe these findings on ultrasound.
5. Identify the female and male pelvis sonographic anatomy and scanning procedure.
6. Define the sonographic criteria of an intrauterine pregnancy and 1st trimester findings.
7. Understands the limitations of ultrasound in maternal trauma.

Week 8: Trauma and Undifferentiated Shock

1. Demonstrate an understanding of the basic eFAST and RUSH exam views and commonly presenting physiology and pathology.
2. Demonstrate the theoretical application of the eFAST and RUSH exam.
3. Understand the limitations of ultrasound in trauma and continued evaluation.
4. Demonstrate the theoretical knowledge of how to obtain abdominal views and evaluate images using the appropriate views and techniques for interrogating the presence of free fluid.
5. The learner will recognise the presence of free fluid and how this may extend into other peritoneal spaces.
6. The learner will understand the importance of sonographic landmarks and the mis-identification of free fluid.

Week 9: Procedural Guided Ultrasound

1. Have the knowledge to safely perform a facia iliaca/nerve block under ultrasound guidance.
2. Have the knowledge to safely perform ultrasound guided peripheral intravenous cannula placement and understands the concept of inline needle tip management.

3. Has knowledge of arterial line placement using ultrasound.
4. Understands the limitations of ultrasound within cardiac arrest management.
5. Has the knowledge to integrate ultrasound seamlessly into cardiac arrest for non-shockable rhythms of PEA cardiac arrest.
6. Has the knowledge to diagnose cardiac tamponade and the use of ultrasound for a pericardiocentesis procedure.

Week 10: Community Care Ultrasound

1. The learner has knowledge of ultrasound applications for low acuity medical and accidental injuries.
2. The learner understands the limitations of ultrasound with emphasis on contraindications for skin infections and open fractures.

Week 11: Critical Care Paramedic Ultrasound Applications and Extensions

1. The learner will be able to identify sonographic upper airway anatomical landmarks consistent with those used in surgical cricothyroidotomy.
2. The learner will have theoretical knowledge of endotracheal intubation sonographic airway management.
3. The learner will broaden their knowledge looking at future applications of ultrasound including transcranial doppler and the limitations of this prehospital.
4. The learner will have theoretical knowledge and application of ultrasound in Deep Vein Thrombosis (DVT).
5. The learner will have theoretical knowledge, applications, limitations and cautions of ocular ultrasound in the prehospital environment.

Week 12: Bringing it all together – Case Studies

1. The learner should feel confident reviewing POCUS ultrasound images including; probe used, ultrasound imaging window, depth of image, focal point, anatomical region and plane of imaging.
2. The learner interprets POCUS findings using sonographic terminology.
3. The learner professionally documents POCUS ePRF findings.
4. The learner understands the limitations of POCUS and integration into paramedic practice and therefore has the knowledge to safety-net patients with appropriate referral and patient follow-up.

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Business Case (Australasia)

This course aims to create a pathway for paramedic ultrasound in Australasia with the support of ASUM.

This proposal provides two clinical pathways 1) paramedic and 2) extended care paramedic. Modules within the CPPU pathway would be chosen in accordance with clinical practice.

The current model of care includes the paramedic attending the patient, providing clinical assessment and deciding if the patient requires emergent hospital care or community care. Often these treatment decisions are based on a physical exam and patient history. Ultrasound provides an enhanced diagnostic ability, filtering differentials such as dry versus wet lungs and identification of an acute AAA pathway as an example.

As the traditional model of ambulance care is re-evaluated there is more requirement for Extended Care Paramedics (ECP) to see and treat the patient at home, in a clinic or in the community without hospitalisation. The ECP scope of practice has grown since its introduction in 2009. The ECP scope includes low acuity work and some examples of conditions managed in the community include the management of urinary retention, urinary catheters, community-acquired pneumonia, cellulitis and renal colic. Many of these presentations would receive a routine ultrasound in ED. In the community, ultrasound would help inform decisions and provide a clinical safety net for the patient. One of many examples where an ECP could use ultrasound is for examination of the kidneys and bladder volume pre and post void. This provides the ECP with vital information and can assist with the clinical decision making and treatment for patients.

In New Zealand, there are over 1700 paramedics registered with Kaunihera Manapou, Paramedic Council. Although Kaunihera Manapou, Paramedic Council authorise an annual practising certificate, at the time of writing, there is no mention of ultrasound being included in the paramedic scope or documentation on their website. Specialist skills such as ultrasound are being considered within this scope.

Currently, the use of ultrasound by paramedics in the prehospital environment is in its infancy. The most prominent use of ultrasound is by critical care flight paramedics working in the aeromedical environment. Ultrasound is carried on Auckland Helicopter Emergency Medical Service (HEMS), Northland Rescue Helicopter and all Search and Rescue Services Limited (SRSL) helicopters except the helicopter in Wellington. Recently, Garden

City Helicopters (GCH) has introduced the CAHPU (Certificate in Allied Health Performed Ultrasound) eFAST module as a standard requirement for their flight paramedics.

In the road ambulance setting, St John Ambulance is intending to conduct an NZ-wide Extended Care Paramedic ultrasound pilot trial for which all participants have taken the RADY801 course which I teach and lead. Wellington Free Ambulance is conducting a pilot trial of ultrasound commencing with critical care flight paramedics in 2023. Internationally prehospital ultrasound has been widely adopted with a continuously growing list of diagnostic applications. Ultrasound has been used within Ambulance Victoria since 2014 for eFAST and vascular access (B. Meadley, Personal Communications, July 23, 2022). Their MICA flight paramedics complete a yearly 1-hour online Mandated Practice Skill Set (MPSS) to maintain their authority to practise POCUS.

Barriers for Paramedicine

At present, the CAHPU is available for allied clinicians including paramedics. Relevant modules include eFAST, vascular access and basic early pregnancy. It is clear that paramedics could benefit from the addition of units previously reserved for the CCPU such as AAA, basic soft tissue, proximal DVT, renal hydronephrosis and calculi, FELS, lung, pleural effusion, and rapid cardiac echocardiography (basic). These modules are taught within the RADY801 course.

Paramedics follow a set of national clinical practice guidelines that allow interagency planning and cross-region familiarity. During the Wellington Free Ambulance pilot trial, prehospital ultrasound guidelines would be developed to emulate the ASUM guidelines. These would be local guidelines initially with the scope to publish nationally.

In order for this to be successful, it is important that logbook requirements are completed to show competence and experience gained through physical scanning. However, in New Zealand, there is no provision for paramedics to scan in emergency departments making the requirements difficult to achieve. The requirement of 25 scans per unit is achievable, however five positive scans may take years to achieve making the process less appealing to the paramedic. The next section outlines a proposed pathway to accommodate log book requirements.

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Proposed CPPU Pathway

This section will describe the proposed CPPU process. Registered paramedics in New Zealand would apply for the AUT RADY801 12-week ultrasound course. Once accepted paramedics will be asked to join ASUM as a member. The 12-week ultrasound course provides adequate knowledge and training to commence logbook entries on completion. Prior to course completion paramedics are required to attend the two-day block course where ASUM formative assessments can occur with accredited assessors. As this is a proposed pathway a requirement for a third day maybe added for assessment purposes only. This addition would allow the three-day block course to retain the same hours of training thus not disadvantaging students. These assessments ensure safe, appropriate and confident scanning.

After successful formative assessments, the paramedic may use ultrasound in accordance with their clinical practice guidelines in a non-diagnostic capacity for no less than six months. This is to allow the paramedic time to consolidate learning and become comfortable with integration into everyday clinical practice. During this time if there is a life-threatening diagnosis such as pericardial tamponade the paramedic can consult and seek advice. During the six-month probationary period, paramedics will complete the ASUM log book. The paramedics will undergo summative assessments during this time which will allow clinical and diagnostic use once signed off by ASUM.

Paramedics would be required to maintain their CPD and registration in accordance with ASUM guidelines which includes paramedics to complete at least 50% of the original logbook requirements per year, for five years. All entries must be clinically indicated. Record at least five points of relevant CPD per year for each unit, for five years. The maximum number of CPD points required per year for each candidate is a total of 15 points. A refresher ultrasound one-day through AUT University will be proposed on a yearly basis to maintain clinical knowledge and competence. Below is a summary of the proposed CPPU pathway:

CERTIFICATE IN PARAMEDIC PERFORMED ULTRASOUND PROPOSAL 2022

Summary CPPU Pathway

Who can apply:

Registered paramedics*

Approved course:

12 week Auckland University of Technology RADY801

Block course (formative assessments) additional day for assessments (3-days total)

Log book:

6 months of non-diagnostic ultrasound scanning in the field

25 scans of each type with three positive scans from each

Image Audit:

Cloud based storage, platform dependant

Review scans, provide feedback and develop other interested clinical leads

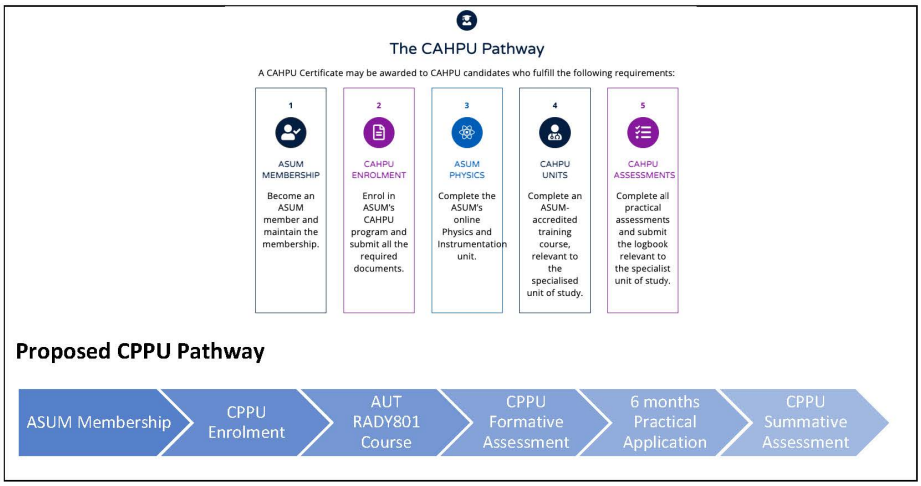
Summative Assessment:

Summative assessments during the 6mths of scanning in the field

Remedial scanning and education as required

Credentialling:

ASUM CPPU, refresher course yearly (1-day)



Pilot Trial

Wellington Free Ambulance are in the process of commencing a pilot ultrasound trial with four critical care flight paramedics who I work with directly with as a flight paramedic. This small cohort would be an ideal group to pilot the CPPU concept.

* Paramedic, Critical Care Paramedic and Extended Care Paramedic

CERTIFICATE IN PARAMEDIC PERFORMED ULTRASOUND PROPOSAL 2022

Summary

In summary, this paper has presented the concept of a Certificate in Paramedic Performed Ultrasound (CPPU) designed by paramedics for paramedics. The support of ASUM is crucial to the continued development of ultrasound and to ensure the safe practice of ultrasound prehospital. ASUM would benefit financially with increased membership and awareness within the prehospital community.

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