Healthcare professionals' perceptions and knowledge of the management and removal of underwater seal chest drains in children and young people: New Zealand

Jacqueline Lawless

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Attestation of Authorship

I hereby declare that this 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 (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Jacqueline Lawless

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Abbreviations

CT	**Chest Tube**
CHD	**Congenital Heart Disease**
CPT	**Current Procedural Terminology**
CXR	**Chest X-Ray**
CYP	**Children and Young People**
Fr	**French**
FRACS	**Fellow of the Royal Australasian College of Surgeons**
ICD	**Internal Classification of Disease**
ICU	**Intensive Care Unit**
IOA	**Intensive Observation Area**
IR	**interventional radiology**
JBI	**Joanna Briggs Institute**
Kg	**Kilogram**
MBChB	**Bachelor of Medicine and Bachelor of Surgery**
MD	**Doctor of Medicine**
mL	**millilitres**
mm	**millimetre**
NICU	**Neonatal Intensive Care Unit**
NP	**Nurse Practitioner**
PgCertHSC	**Post Graduate Certificate of Health Science**
PgDipHsc	**Post Graduate Diploma of Health Science**
PICU	**Paediatric Intensive Care Unit**
PRISMA	**Preferred Reporting Items for Systematic and Meta-Analyses**
PVG	**Practice Validation Guideline**
SPIDER	**Sample, Phenomenon of Interest, Design, Evaluation and Research**
USA	**United States of America**
UWSCD	**Underwater Seal Chest Drain**
VATS	**Video Assisted Thoracic Surgery**
6h	**6 hours**

Chapter One: Title and Abstract

1.1 Title:

Healthcare professionals' perceptions and knowledge on the management and removal of underwater seal chest drains in children and young people: New Zealand.

1.2 Thesis Abstract:

Paediatric patients with underwater seal chest drains are cared for in certain areas within a paediatric hospital setting. Presently within a paediatric hospital in New Zealand there is a clinical underwater seal chest drain guideline to guide chest drain insertion, management, and removal yet there is inconsistency in what the guideline states and current practice. This quality improvement project undertook a integrative review of the international literature on underwater seal chest drain management and explored healthcare workers perceptions and knowledge on the management and removal of underwater seal chest drains in children and young people at a large children's hospital in New Zealand.

Method: An integrative review was undertaken to summarise previous international empirical peer-reviewed literature published from 2011 - 2022 to provide a comprehensive understanding on the management and removal of underwater seal chest drains in children and young people. A qualitative design using face-to-face interviews with healthcare professionals from one large children's hospital in New Zealand who had a key role in underwater seal chest drain management and removal was undertaken in 2022.

Analysis: The integrative review and face to face interview data were analysed separately using the six phases of Braun and Clarks' (2006) thematic analysis. This included familiarising oneself with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes and generating a report. The findings of both research designs were brought together in the discussion.

Results: A total of nine studies were included in the review. An inductive analysis of nine manuscripts generated one theme (disparity in healthcare professionals' knowledge and practice with underwater seal chest drain management), three sub-themes (healthcare professionals, practice considerations, adverse events) and nine categories (discipline and context, knowledge, education, indications, underwater seal chest drain tubing and characteristics, management, assessment, complications, interventions). Face to face interviews were undertaken with seven healthcare professionals. An inductive analysis of the interviews generated one theme (a gap between theory, guidelines and practice of underwater seal chest drain management), four subthemes (management, practice considerations, scope of practice, current practice), eleven categories (collaboration, care delivery, indications, insertion-removal, adverse events, guidelines, knowledge, demographics, reality, ability, context). The results highlighted that there

was a disparity in healthcare professionals' knowledge and practice with underwater seal chest drain management as well as a gap between theory, guidelines and reality of practice for underwater seal chest drain management.

Conclusion: There is a lack of research for underwater seal chest drain management and removal, particularly in paediatrics. There is a discrepancy between healthcare professionals' perceptions and knowledge of underwater seal chest drain management and removal, to what is required to manage and remove underwater seal chest drains safely and effectively. There is an urgent need to provide healthcare professionals with the relevant education and knowledge to be able to adequately care for children with underwater seal chest drains and ultimately prevent any adverse events. It is also recommended that healthcare professionals utilise contemporary evidence-based research to create and update clinical practice guidelines for underwater seal chest drain management and removal.

Key words: Children, Hospital, Management, New Zealand, Paediatrics, Removal, Underwater Seal Chest Drains, Young People

Chapter Two: Introduction

2.1 Introduction

Chest drains also known as underwater seal chest drains (UWSCD) are inserted in children and young people (CYP) for conditions where fluid requires draining (chylothorax, haemothorax, pleural effusion and empyema) or there is a need to drain air (pneumothorax and tension pneumothorax) or for post-operative drainage following cardiac surgery or a thoracotomy (Simons & Ramesh, 2019; Theodorou, Hegazi, Moore, & Beres, 2021). UWSCDs allow for drainage of air, blood or fluid to help reinflate the lungs and restore negative pressure in the pleural cavity (Seyma, Meral, & Atiye, 2021). The purpose of UWSCDs is to prevent air or fluid going back into the chest (The Royal Children's Hospital Melbourne, 2016). The underwater seal also allows for easy identification of air drainage through bubbling in the water and fluctuations or swinging of the fluid as influenced by CYP's respiration, being inspiration and expiration. (The Royal Children's Hospital Melbourne, 2016). The fluctuations decrease as the pneumothorax resolves however, if the fluctuations discontinue unexpectedly then this could indicate a blockage or kink in the tubing, which should be corrected promptly (The Royal Children's Hospital Melbourne, 2016).

Complications of UWSCD insertion can include damage to the nearby organs, subcutaneous emphysema, intercostal neuralgia, chylothorax and horner syndrome (Seyma et al., 2021). Other potential complications with UWSCDs include pneumothorax, bleeding at the drain site, infection of the insertion site, a retained drain, accidental disconnection or removal (McGrath, Ranstrom, Lajoie, McGlynn, & Mooney, 2017; Theodorou et al., 2021). Clamping an UWSCD too early could also lead to a tension pneumothorax (Chan, Yu, Kwok, Yeung, & Yu, 2021). If there is an air leak present, the site should be inspected for a leak and the dressing reinforced with an occlusive dressing if required (The Royal Children's Hospital Melbourne, 2016). An air leak can indicate a pneumothorax and a persistent air leak could potentially lead to a tension pneumothorax which is a medical emergency (Chan et al., 2021).

When caring for CYP with an UWSCD nursing assessment entails checking and documenting regular vital signs including temperature, heart rate, blood pressure, respiratory rate, oxygen saturations and assessment of a patients work of breathing (Hutching & Sanchez, 2020; The Royal Children's Hospital Melbourne, 2016). Pain assessment is also vital as having an UWSCD in place can be very painful for CYP (Levent Kıy, Demiray, & Boran, 2022). It is important that CYP's

pain is well managed to ensure they continue to be able to breathe deeply and cough, as well as mobilise (Levent Kıy et al., 2022). If CYP are unable to breathe effectively, clear secretions with coughing or mobilise, further complications could occur such as infection, atelectasis, or hypoxaemia (Levent Kıy et al., 2022). In addition, assessment and documentation of the insertion site should be carried out hourly, checking for signs of infection or inflammation and that the dressing is secure and intact (Hutching & Sanchez, 2020). Checking the unit and tubing, suction, drainage, air leak/bubbling, oscillation/swinging/fluctuations and emergency equipment (clamps, suction, oxygen) is also required (Hutching & Sanchez, 2020). A nurse further needs to check and document the output from the drain, whether that be air or fluid, hourly volume and total volume drained and characteristics (colour and consistency) of fluid drained (Hutching & Sanchez, 2020). The doctor/surgeon's responsibility entails assessing CYP's indication for an UWSCD and inserting an UWSCD if it is clinically indicated (Simons & Ramesh, 2019). The doctors and surgical team are also required to review the overall status of CYP, reviewing the documentation including the drainage output and identify when an UWSCD is ready for removal (Azzi et al., 2019). In addition, the doctor/surgeon should be notified if the nursing staff have concerns related to the UWSCD or CYP's status (Hutching & Sanchez, 2020). Indications for removal are when the fluid output is less or non-existent and the drain is no longer bubbling (Azzi et al., 2019; Chan et al., 2021).

Of concern, international paediatric hospital guidelines for UWSCD management and UWSCD removal are utilising outdated literature and there appears to be minimal recent evidence available to develop effective UWSCD clinical guidelines (Grady, 2018; Grady & Cairney, 2018a, 2018b; Hutching & Sanchez, 2020; Leicester Children's Hospital, 2019; The Royal Children's Hospital Melbourne, 2016). The National Health Service Greater Glasgow and Clyde provides separate guidelines for insertion, management and removal of UWSCD for health professionals caring for CYP with UWSCDs (Grady, 2018; Grady & Cairney, 2018a, 2018b). However, it is significant to note that these guidelines are overdue for a review and potential update (Grady, 2018; Grady & Cairney, 2018a, 2018b). Clinical guidelines that are not up to date are at risk of being irrelevant secondary to the constant changes in healthcare and evidence-based research (Flynn Makic, Rauen, Jones, & Fisk, 2015). Of concern, the Royal Children's Hospital in Melbourne UWSCD guideline cites a systematic review carried out by Charnock and Evans in 2001, twenty years ago (Charnock & Evans, 2001). Charnock and Evans carried out a systematic review to evaluate the evidence available for nursing management of UWSCDs and identified there was minimal research available for the nursing management of UWSCDs, particularly in CYP, a finding that remains applicable to this day (Charnock & Evans, 2001). Leicester Children's Hospital also has a guideline available for medical, nursing and allied health staff to guide clinical practice

(Leicester Children's Hospital, 2019). This guideline is similar to the Royal Children's Hospital, as it provides guidance on insertion, management and removal, yet this guideline references four articles dated from 2003 to 2014 and is due for review in September 2022 (Leicester Children's Hospital, 2019). These two international guidelines highlight that UWSCD removal is carried out by two competent healthcare professionals, nurses or doctors (Leicester Children's Hospital, 2019; The Royal Children's Hospital Melbourne, 2016). There is an evident need for an update in literature to influence guidelines globally, with a requirement for paediatric hospitals to ensure that these guidelines that guide clinical practice are evidence-based and routinely reviewed and updated.

One paediatric hospital in New Zealand presently has four guidelines related to UWSCD management that are reviewed every two years (Hamer & McCarthy, 2021; Hutching & Sanchez, 2020; Newborn Services Clinical Practice Committee, 2018; Primhak et al., 2022). The main clinical guideline titled *'Chest drains in children'* provide staff with information on UWSCD drainage system, insertion, connections, dressings, suction, management, maintaining patient safety and was last reviewed in August 2021 (Hutching & Sanchez, 2020). The literature used to develop and review this guideline range from 1992 to 2010, with no contemporary literature cited. This clinical guideline also states an UWSCD can be removed by a doctor or a trained nurse in the cardiac or paediatric intensive care unit (PICU) (Hutching & Sanchez, 2020). UWSCDs are cared for in other areas within this hospital, therefore it will be valuable to assess healthcare professionals' perceptions and knowledge on UWSCD removal being completed by trained staff in areas other than the cardiac ward or PICU.

The other three UWSCD guidelines in the paediatric hospital in New Zealand are '*Empyema*,' '*Ambulatory chest drains*,' and *'Chest drains in the neonate'* (Hamer & McCarthy, 2021; Newborn Services Clinical Practice Committee, 2018; Primhak et al., 2022). The clinical guideline titled *'Empyema'* reviews UWSCD management in CYP with empyema and was last updated in August 2022 (Primhak et al., 2022). This guideline contains an algorithm which states that if CYP have a large effusion, moderate to severe respiratory distress or a persistent fever they must have an ultrasound scan and be referred to the surgical team for insertion of an UWSCD. When CYP require an UWSCD they are then under the care of the surgical team until UWSCD removal. The empyema guideline also highlights UWSCD set-up, maintenance and removal as well as the use of anti-fibrinolytics such as urokinase. Empyema can be managed by video assisted thoracic surgery (VATS) or with anti-fibrinolytic's via the UWSCD (Pacilli & Nataraja, 2019). Of concern, the *'Ambulatory chest drains'* guideline which is relevant to PICU and the cardiac ward does not site any references and was last updated in January 2021 (Hamer & McCarthy,

2021). On day two post cardiac surgery if there is no bubbling evident in the UWSCD and the fluid drainage is less than 100mL, the UWSCD is switched over to an ambulatory UWSCD. Also of concern is the last guideline *'Chest drains in the neonate'* referred to in the main guideline *'Chest drains in children'* references only two articles from 2007 and 2009 and has not been updated since 2018 (Newborn Services Clinical Practice Committee, 2018).

UWSCD insertion, management and removal is distinctly complex (Basler & Englund, 2020; Kamio, Iizuka, Koyama, & Fukaguchi, 2022). To prevent adverse events, complications and reduce risk, it is imperative that the medical and nursing staff are completely aware of the latest evidence-based literature, guidelines, policies and required competencies in how to safely manage UWSCD in CYP (Kesieme, Essu, Arekhandia, Welcker, & Prisadov, 2016; Magner, Houghton, Craig, & Cowman, 2013). Magner et al (2013) concluded that having up to date guidelines will ensure adequate UWSCD management, therefore it is vital to ensure relevant literature is utilised to develop effective evidence based contemporary UWSCD clinical guidelines. There is an abundance of research related to the implications, diagnoses, interventions, and benefits/deficits in UWSCD treatment in CYP (Bender, Ward, Iocono, & Saha, 2015; Williams, Baumann, Grabowski, & Lautz, 2019) with a gap in the literature specific to UWSCD management and removal within CYP globally (Magner et al., 2013; McGrath et al., 2017; Theodorou et al., 2021). The lack of standardisation around UWSCD management and removal provides an opportunity for a quality improvement project to direct further practice, guideline development and educational initiatives on the management and removal of UWSCD at a large children's hospital in New Zealand.

Chapter Three: Research Design/Methods/Methodology

3.1 Research Design

The study design includes an integrative review and face-to-face interviews with up to ten healthcare professionals from a large children's hospital in New Zealand.

3.2 Integrative Review

As a method, an integrative review summaris previous empirical or theoretical literature to provide a more comprehensive understanding of a particular issue or healthcare (Whittemore & Knafl, 2005). Integrative reviews are useful in informing research, practice, and policy initiatives (Whittemore & Knafl, 2005). An integrative review has been chosen for this research project as it facilitates the involvement of science and theory, and thus results in best evidence-based practice for nurses (Toronto & Remington, 2020). This project will include primary empirical international peer reviewed published studies from 2011 to 2022 on the management and removal of UWSCDs within a paediatric hospital setting.

3.2.1 Research Question

What is reported in the literature on healthcare professionals' perceptions and knowledge on the management and removal of UWSCDs within a paediatric hospital setting?

3.2.2 Aim

To undertake a critical review of the literature on healthcare professionals' perceptions and knowledge on the management and removal of UWSCDs within a paediatric hospital setting.

3.2.3 Sample

The Sample, Phenomenon of Interest, Design, Evaluation and Research (SPIDER) type tool was utilised in this review as represented in Table 1 (Polit & Beck, 2021).

Table 1: The SPIDER

Sample	Healthcare professionals
Phenomenon of Interest	The management and removal of UWSCDs in paediatric hospital settings
Design	Integrative Review
Evaluation	Identification of key issues on UWSCD perceptions and knowledge on management and removal

Research type	Empirical international peer-reviewed manuscripts
UWSCD underwater seal chest drain	

3.2.4 Data Collection

Search Strategy

The following five electronic databases Cumulative Index to Nursing and Allied Health Literature (CINAHL), Psych Info, PubMed, Medline and Scopus were used in the search. These databases were chosen as they cover research in healthcare professionals and healthcare delivery on the management and removal of UWSCDs in CYP, which are considered relevant to the topic of this integrative review. The search parameters included English language, peer reviewed, full text, empirical studies published between 2011 to 2022. The following key search terms used in the database searches were paediatric or pediatric or infant or children or adolescents or youth or child or teenager AND perceptions or views or experiences AND knowledge AND underwater seal chest drain or chest drain or chest tube or thoracic drain AND healthcare professionals or nurses or staff or healthcare workers or doctor or surgeon AND hospital or acute setting or inpatient or ward AND treatment or management or intervention or removal.

Inclusion Criteria

- Children and adolescents aged from new-born to 21 (World Health Organisation, 2022)
- Healthcare professionals' perceptions/knowledge on UWSCD management and/or removal
- Hospital setting
- Empirical studies focused on the management and removal of UWSCDs within a paediatric hospital setting
- English language
- Full text
- Peer-reviewed
    - Studies published in 2011 up to June 2022

Exclusion criteria

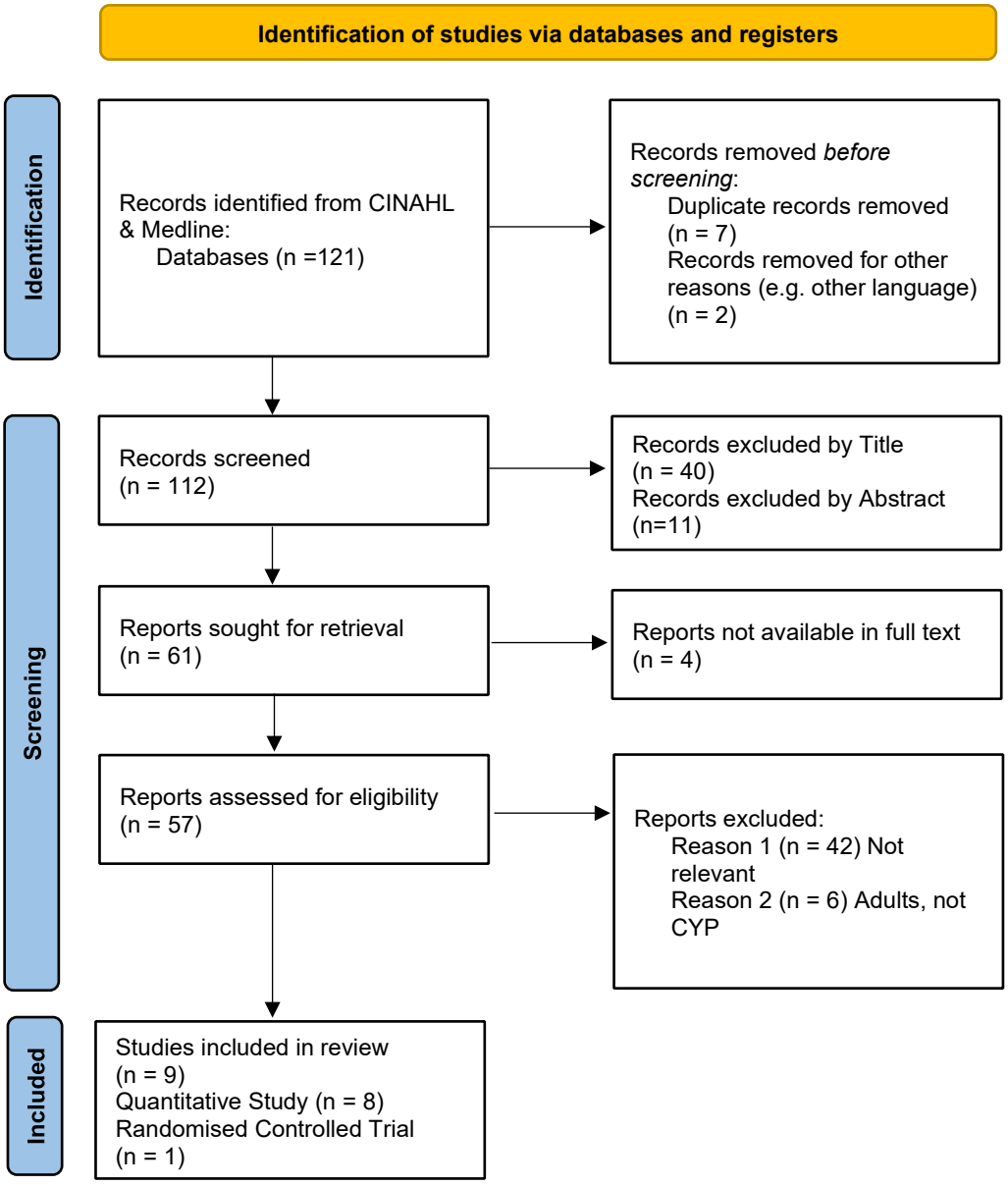
- Articles where the focus was not on the management and removal of UWSCDs within a paediatric hospital setting

The purpose of inclusion and exclusion criteria was to ensure the database search yielded only current, high-quality credible studies that focused on healthcare professionals' perceptions/knowledge on UWSCD management and/or removal within a paediatric hospital setting.

3.2.5 Search Outcome

The search in the databases after combining the results from all search terms/keywords and then removing duplicates resulted in 112 articles. Titles were screened, with the abstracts being reviewed for any articles that were of relevance to answer the research question. Of the 112 articles, 57 met the criteria for full text reading, these articles were downloaded, read in full and re-assessed against the inclusion/exclusion criteria. At this stage, 48 articles were excluded as they did not meet the inclusion criteria leaving nine articles for inclusion in this integrative review. A review of the reference list from the nine included studies identified no additional studies. The PRISMA flow chart summarising this process is represented in Figure 1 (Moher, Liberati, Tetzlaff, & Altman, 2009).

3.2.6 Figure 1: PRISMA Flow Chart



Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart (Moher et al., 2009).

3.2.7 Quality Appraisal

The articles that met full text screen against the inclusion/exclusion criteria were then assessed for quality using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for quantitative and randomised controlled trial research (Joanna Briggs Institute, 2022). The purpose of the quality appraisal process was to determine the methodological quality of the selected studies, to address possible bias in the design, analysis and conduct of the research (Joanna Briggs Institute, 2022). After the initial appraisal by the student, articles were then critically appraised by the primary supervisor, to ensure rigour in the analysis (Knafl & Whittemore, 2017). If there were any disagreement between scores these were then discussed until a consensus was agreed. No manuscripts were excluded based on a low critical appraisal score as all manuscripts that met the inclusion criteria were important to include.

3.2.8 Data Extraction

A data extraction table was used to compile relevant information across the studies and to promote rigor within the review (Whittemore & Knafl, 2005). The data extraction table included the title, aim, authors, year of publication, design, population, data collection methods, findings, recommendations, and critical appraisal scores.

3.2.9 Data Analysis

The data was analysed using the following six phases of Braun and Clarks' (2006) thematic analysis. This included familiarising yourself with your data (reading and re-reading and noting down any initial ideas), generating the initial codes (coding the findings of the data), searching for themes (collating codes into possible themes and gathering data relevant to each theme, and identifying the relationships between the codes and themes), reviewing the themes (checking if the themes are appropriate in relation to the coded extracts and the entire data set), defining and naming the themes (ongoing analysis to refine the specifics of each theme and the generation of clear definitions and names for each theme) and generating a report (the production of a scholarly report of the analysis) (Braun & Clarke, 2006).

3.2.10 Ethics

As this study was an integrative review utilising already published material, ethics approval was not required. However, the author completed this research in an ethical manner to maintain authenticity of previous work and by ensuring that exact data was extracted from the included articles.

3.3 Interviews:

The study included a qualitative design using face-to-face interviews with healthcare professionals from one large children's hospital in New Zealand who had a key role in UWSCD management and removal.

3.3.1 Research Question

What are healthcare professionals' perceptions and knowledge on the management and removal of UWSCDs at a paediatric hospital in New Zealand?

3.3.2 Aim

To explore healthcare professionals' perceptions and knowledge on the management and removal of UWSCDs from one paediatric hospital in New Zealand.

3.3.3 Setting

The paediatric hospital in New Zealand contains seven specialty wards and includes a PICU and neonatal intensive care unit (NICU). Areas that care for patients with UWSCDs were selected, these included the paediatric surgical ward, paediatric cardiac ward and PICU.

3.3.4 Participants

Purposive sampling of ten healthcare professionals who have a key role in UWSCD management and removal both in the medical and nursing discipline from one paediatric hospital in New Zealand. The author sent an email invitation to the healthcare professionals that included the participant information sheet and consent form (Appendix A, B).

3.3.5 Inclusion Criteria

Healthcare professionals who have a key role in UWSCD management from either the surgical, cardiac and intensive care areas from one paediatric hospital in New Zealand. Voluntary informed signed consent and a good understanding of the English language.

3.3.6 Interviews:

Once the participants contacted the author by email and had verbally consented to participate in the quality improvement project, the author set up a time that was convenient for each participant to complete the interview at the paediatric hospital. The consent form was signed by the participant and author and further questions were answered before the interview was undertaken

(Appendix B). All interviews were recorded, and demographic data collected included discipline, years of paediatric experience, highest degree attained, UWSCD qualifications and further education or competencies attained.

Open-ended questions

Twelve questions were generated from the integrative literature review. These questions were developed to explore healthcare professionals' perceptions and knowledge on the management and removal of UWSCDs within the paediatric hospital. The interview guide was pilot tested with three experts in the field of UWSCD management and removal prior to undertaking the interviews. Following the pilot interview two questions were re-worded to ensure better readability and comprehension (Table 2).

3.3.7 Table 2: Interview Questions

1	What are the indications for chest drains in children at this hospital and what is your understanding of these?
2	What is your understanding of chest drain management at this hospital?
3	Where are patients cared for with chest drains in this hospital?
4	What are your views on this? Do you envisage this changing?
5	What is your understanding on the care required for patients with chest drains at this hospital?
6 .	What is your understanding of the indications for chest drain removal at this hospital?
7 .	What is your understanding of chest drain removal at this hospital?
8 .	What is your understanding on what is required post chest drain removal at this hospital?
9 .	Do you think nursing staff at this hospital can be trained to remove chest drains? Please explain your answer.
10 .	What is your understanding on the education provided to staff at this hospital before caring for a patient with a chest drain?
11 .	What would you like to see in the future at this hospital for paediatric patients with chest drains?
12 .	Do you have anything that you would like to add?

. . . .

3.3.8 Analysis

The recorded interviews were transcribed verbatim by the author. The transcripts were analysed using the following six phases of Braun and Clarks' (2006) thematic analysis. This included familiarising yourself with your data (reading and re-reading and noting down any initial ideas), generating the initial codes (coding the findings of the data), searching for themes (collating codes into possible themes and gathering data relevant to each theme, and identifying the relationships between the codes and themes), reviewing the themes (checking if the themes are appropriate in relation to the coded extracts and the entire data set), defining and naming the themes (ongoing analysis to refine the specifics of each theme and the generation of clear definitions and names for each theme) and generating a report (the production of a scholarly report of the analysis) (Braun & Clarke, 2006).

3.3.9 Ethics

The Nursing Director and Safety and Quality Governance Group at the paediatric hospital provided consent for this practice project to be undertaken as a quality improvement project. The findings from the healthcare professional's interviews will be presented to the Nursing Director and Safety and Quality Governance Group at the paediatric hospital to direct further practice, guideline development and educational initiatives on the management and removal of UWSCDs at the paediatric hospital. The integrative review will be submitted for consideration to be published in a peer-reviewed journal. The name of the paediatric hospital in New Zealand has not been stated including the healthcare professionals' identity to ensure confidentiality and anonymity is upheld. There was no conflict of interest to report with interviewing the healthcare professionals at the hospital. In addition, all information, consent forms, recordings and transcripts were securely stored in a locked filing cabinet and/or password protected computer at the paediatric hospital. Only the author and primary supervisor had access to these documents.

Chapter Four: Results/Findings

4.1 Integrative Review

4.1.1 Results

The nine manuscripts comprised of four retrospective chart/database reviews (Kamio et al., 2022; Kanamori, Guner, Gibbs, & Schomberg, 2021; Pouraboli, Mirlashari, Fakhr, Ranjbar, & Ashtari, 2021; Theodorou et al., 2021), three descriptive quantitative studies (Magner et al., 2013; Taylor, Bates, & Kipps, 2018; Woodward, Dowling, Taylor, & Savin, 2013), one non-experimental design (Ring & Watson, 2017) and one randomised controlled trial (Pouraboli et al., 2021) that spanned across four countries as represented in Table 3. Most of the studies were undertaken in the United States of America (USA) (Kanamori et al., 2021; LaGrasta, McLellan, & Connor, 2021; Ring & Watson, 2017; Taylor et al., 2018; Theodorou et al., 2021; Woodward et al., 2013), one in Ireland (Magner et al., 2013), one in Iran (Pouraboli et al., 2021) and one in Japan (Kamio et al., 2022). The JBI critical appraisal scores for the nine manuscripts ranged from 3/8 to 8/8 and 8/13 (Table 3) (Joanna Briggs Institute, 2022). Six of the included studies reviewed UWSCD removal, focusing on pain management during removal or the requirement for chest X-rays post removal (Kanamori et al., 2021; LaGrasta et al., 2021; Pouraboli et al., 2021; Ring & Watson, 2017; Theodorou et al., 2021; Woodward et al., 2013). Two studies focused on the management of UWSCDs, nurses' knowledge of the management of UWSCDs or the variability of management in paediatric cardiac centres (Magner et al., 2013; Taylor et al., 2018) and one study reported adverse events around chest tube insertion and thoracentesis (Kamio et al., 2022) (Table 3).

4.1.2 Findings

An inductive analysis of the findings generated one theme (disparity in healthcare professionals' knowledge and practice with UWSCD management), three sub-themes (healthcare professionals, practice considerations, adverse events), nine categories (discipline and context, knowledge, education, indications, UWSCD tubing and characteristics, management, assessment, complications, interventions) and included 101 codes and 131 findings as represented in Table 4.

Disparity in healthcare professionals' knowledge and practice with UWSCD management

It was evident across all the manuscripts incongruity exists between what various healthcare professionals of different disciplines and areas of practice are stating is required for UWSCD management and removal in CYP and what is occurring in practice.

Healthcare Professionals

Healthcare professionals included three categories (discipline and context, knowledge, education) and included 18 codes and 24 findings that were evident across four manuscripts (Kanamori et al., 2021; Magner et al., 2013; Ring & Watson, 2017; Theodorou et al., 2021). It was reported in the literature that UWSCDs were inserted by healthcare professionals from various disciplines (intensivists, emergency doctors, surgeons, registrars, consultants), and within different clinical settings (operating theatres, emergency departments, general wards, critical care units, radiology departments) (Kanamori et al., 2021; Theodorou et al., 2021).

'Pigtail chest tubes were most commonly placed in the pediatric intensive care unit (50.4%), followed by interventional radiology (13%), the operating room, and the emergency department (12.2%). The remainder were placed on the pediatric ward, the surgical intensive care unit and the neonatal intensive care unit' (Theodorou et al., 2021) (p.2).

The literature identified that the healthcare professional's role/position and their experiential or perceived knowledge of UWSCD management and removal was influenced by the degree of contact they had with UWSCDs and those that regularly worked with patients with UWSCDs had greater knowledge and skill (Magner et al., 2013). However, when an UWSCD knowledge test was undertaken with nurses who worked with UWSCDs and the scores were correlated to the nurses' self-perceived knowledge, there was a large discrepancy between what nurses perceived they knew and what they actually knew (Magner et al., 2013; Ring & Watson, 2017).

'The mean score in the knowledge test was 78% (median 80%, mode 80%, SD 114%, variance 26%) (Magner et al., 2013) (p. 2918).

Despite nurses having a good knowledge on intra-pleural pressure and the indications and site for chest drain insertion, it was reported that nurses lacked knowledge regarding the anatomical principles of the lower respiratory tract indicating a deficit in knowledge of physiological structures (Magner et al., 2013). In addition, Magner et al (2013) reported that only half of the healthcare professionals were aware of the significance of bubbling in an UWSCD and those that had more contact with UWSCDs believed that prophylactic antibiotics were mandatory which is a misconception (Magner et al., 2013).

Education included knowledge acquisition gained through in-house workshops, practice guidelines, and being up to date with the state of the science on UWSCDs (Magner et al., 2013). It was reported in one study that over 50% of nurses found in-hospital education as the primary

method to keep updated on UWSCD management whereas 27% of nurses indicated practice guidelines as their primary source of information (Magner et al., 2013). Further sources on keeping abreast on the state of the science on UWSCD management included discussions with colleagues and the education team, the internet, and in attending workshops and conferences (Magner et al., 2013; Ring & Watson, 2017).

'The education team and medical colleagues were frequently cited as sources of information and learning 48% (n=58), as was the internet by 12% (n=15) of respondents' (Magner et al., 2013) (p.2919).

Of interest the healthcare professionals' knowledge on UWSCD management significantly increased ($p<.0001$) after an in-house education workshop that staff reported as being very beneficial to their practice (Ring & Watson, 2017).

Practice Considerations

Practice considerations included four categories (indications, chest drain and tubing characteristics, management and assessment, diagnostics) and included 44 codes and 60 findings that were evident across all nine manuscripts (Kamio et al., 2022; Kanamori et al., 2021; LaGrasta et al., 2021; Magner et al., 2013; Pouraboli et al., 2021; Ring & Watson, 2017; Taylor et al., 2018; Theodorou et al., 2021; Woodward et al., 2013). The literature indicated that common indications for UWSCDs were pleural effusion, pneumothorax, chylothorax, empyema and haemothorax (Kamio et al., 2022; Kanamori et al., 2021; Theodorou et al., 2021).

'The different etiologies of pneumothorax were traumatic (n=22 patients), spontaneous (n=12), post-operative (n=9), barotrauma (n=7), iatrogenic during central venous access (n=2), and necrotizing pneumonia (n=1)' (Theodorou et al., 2021) (p. 2).

The various characteristics of UWSCDs include the type of chest tube used such as a surgical tube or pigtail tube and size of the chest tube which can range from 5 French to 16 French, with 8.5 French being the most common size used (Kanamori et al., 2021; Theodorou et al., 2021). These characteristics as well as the underlying indication and setting in where the UWSCD is inserted are factors that influence the time to UWSCD removal (Kanamori et al., 2021). For example, patients that were admitted to the PICU had a prolonged time to UWSCD removal, with Kanamori et al (2021) theorising that this may be due to the higher acuity of disease in patients within the PICU.

'This study observed a significant difference in the proportion of post-pull CXR patients staying in the ICU (p value = 0.003). An assosciation between ICU stay and time with CT suggests ICU admission is at least one driving factor prolonging time to CT removal. This delay may be clinically driven due to the higher acuity of illness in ICU patients' (Kanamori et al., 2021)(p.632)

There appeared to be significant variability in the day-to-day management of UWSCDs with some healthcare professionals milking the UWSCD tube to maintain patency, suction methods (wall suction, non-wall suction and Jackson-Pratt type bulb suction), administration of oxygen, completing daily or weekly dressing changes and/or when they changed the UWSCD bottles (Magner et al., 2013; Taylor et al., 2018). Taylor et al (2018) reported that the majority of paediatric healthcare facilities had an UWSCD management strategy and 21% of the centres surveyed had a management strategy but this was dependant on the surgeon's preferences which meant there was wide variability in practice (Taylor et al., 2018). It is also significant to note that even though a large proportion of centres surveyed had a management strategy in place, less than half of these centres had this documented in writing (Taylor et al., 2018).

The literature also identified inconsistencies existed with the process and indicators for UWSCD removal in relation to clamping or unclamping prior to removal, removal during inspiration, the level of pleural fluid drainage in ml/kg/tube in 24 hours being an indicator for removal, length of cardiopulmonary bypass, requirement for blood products and consideration in relation to potential thoracic duct injury (Kanamori et al., 2021; Magner et al., 2013; Taylor et al., 2018).

'Of those centres that used specific pleural fluid drainage criteria, some also considered length of cardiopulmonary bypass, requirement for blood product administration, and concern for thoracic duct injury when determining timing of chest tube removal' (Taylor et al., 2018) (p. 1473).

Pain management practices with UWSCD removal were also reported differently in the literature (Magner et al., 2013; Pouraboli et al., 2021; Ring & Watson, 2017). Magner et al (2013) reported that healthcare professionals had a good knowledge of appropriate analgesia for CYP with an UWSCD, yet the healthcare professional's context of care and expertise in UWSCD management was an influential factor in administrating additional analgesics. In addition, Pouraboli et al (2021) highlighted that UWSCD removal was acknowledged by healthcare professionals as a painful procedure and that the use of facilitated tucking in addition to the administration of morphine helped reduce pain during UWSCD removal.

'The majority (78%, n=94) did not agree that additional pain medication should be with-held in case of respiratory depression. Noncritical care nurses were more reluctant than critical care nurses to administer additional analgesia (p = .004)' (Magner et al., 2013) (p. 2918).

The use of chest radiographs appeared to be a common assessment tool across the literature for assessing a patient pre and post UWSCD removal (LaGrasta et al., 2021; Taylor et al., 2018). Kanamori et al. (2021) reported that a significant number of healthcare centres obtained a chest X-ray prior to removal as well as obtaining chest X-rays on the day of UWSCD removal to ensure the removal did not cause a pneumothorax. However, it is important to note that Kanamori et al (2021) found that in almost all patients that had a pre and post removal chest radiograph, there was no change in practice identified.

Adverse Events

Adverse events included two categories (complications, interventions) and included 39 codes and 47 findings that were evident across five manuscripts (Kamio et al., 2022; Kanamori et al., 2021; LaGrasta et al., 2021; Magner et al., 2013; Theodorou et al., 2021). Complications in UWSCD management and removal included readmission to hospital, organ damage, UWSCD misalignment, the need for ventilation, air leaks, vascular injury, surgical hemostasias, kinked or blocked tubes, pneumonia and death (Kamio et al., 2022; Kanamori et al., 2021; LaGrasta et al., 2021).

'The most common complications due to adverse events were lung injury (55%, 75/137), followed by thoracic vascular injury (21%, 29/137), liver injury (10%, 14/137), structural cardiac injury (4%, 5/137), splenic injury (4%, 5/137), and misplacement into the abdominal cavity (4%, 6/137)' (Kamio et al., 2022) (p. 983).

Further complications post removal of an UWSCD included changes in a patient's status and vital signs for example an oxygen requirement, increased work of breathing or deterioration that were further influenced by the child's age, diagnosis, vulnerability, comorbidities, length of chest tube placement, chest tube size and duration of hospital stay (Kanamori et al., 2021). Theodorou et al (2021) identified a link between the size of the chest tube and risk of complications and reported chest tubes that were 8.5 French or smaller were more likely to have complications than larger chest tubes.

'Two clogged, with one requiring thrombolytic therapy (8.5 Fr) and one requiring tube replacement (5 Fr)' (Theodorou et al., 2021) (p. 3).

However, it is important to note that complications reported during UWSCD management and/or removal could also be due to the progression and severity of the underlying illness and not due to UWSCD mismanagement as was evident in four studies (Kamio et al., 2022; Kanamori et al., 2021; LaGrasta et al., 2021; Theodorou et al., 2021).

'Patient required bag-assisted breaths and increased oxygen after CT removal. The post-pull CXR and repeat CXR after continued monitoring were also unchanged, so symptoms were attributed to known severe pulmonary hypertension' (Kanamori et al., 2021) (p. 634).

The risk of complications occurring with UWSCD management and removal has also been linked to the healthcare professionals' degree of experiential knowledge and expertise in UWSCDs (Magner et al., 2013).

'While a good appreciation of the significance of air leaks was evident this was found to be positively associated with level of exposure to chest drains, suggesting good insight through repeated contact (p=.01)' (Magner et al., 2013) (p. 2918).

The necessary interventions for UWSCD complications were either guided by the child's clinical symptoms, clinical status and/or diagnostic tests and were classified as either minor or major interventions (Kanamori et al., 2021). Major interventions which were rare included re-insertion of an UWSCD, return to theatre for a repeat VATS or needle decompression whereas minor interventions included close monitoring and/or a chest X-ray (Kanamori et al., 2021).

'Three of the five patients had a minor intervention of close monitoring and a repeat CXR which was stable; two (1.7%) patients required a major intervention of CT replacement, one of which also returned to the operating room for repeat VATS' (Kanamori et al., 2021) (p.634).

4.1.3 Table 3: Characteristics of Studies

Author	Country	Design	Participants	Data collection	Findings	Recommendations	JBI Score
Title: Nurses' knowledge of chest drain management in Irish Children's Hospital Aim: To explore contact with and knowledge regarding chest drain management among nurses							
Magner, C., Houghton, C., Craig, M., Cowman, S. (2013)	Ireland	Descriptive study.	Critical care and ward nurses (n=121), from one large urban paediatric hospital.	Data were collected over a two-week period by means of a 37-item self-administered questionnaire broadly based on the format of the 'Nurses' knowledge of Chest Drain Management'.	Increased exposure to caring for children with chest drains is synonymous with a greater perception of knowledge levels in this area of practice. While critical nurses looked after children with chest drains more frequently than ward nurses, there was no difference in the knowledge assessment section of the questionnaire.	Those who have less contact with chest drains require regular updates. Robust evidence-based guidelines must be available in the clinical area. Initiatives should be put in place to enhance the clinical skills of nurses.	8/8
Title: The routine use of chest radiographs after chest tube removal in children who have had cardiac surgery Aim: To determine if clinical indicators of pneumothorax are sufficient predictors of the need for chest tube reinsertion in children who have had a chest tube removed after cardiac surgery.							
Woodward, C.S., Dowling, D., Taylor, R.P., Savin, C. (2013)	United States of America	Descriptive study.	53 children under 7years of age who had a CT inserted during their surgery to correct or palliate their CHD from one hospital.	48 item collection tool (demographic data, and a physical examination where signs and symptoms of a significant pneumothorax were documented, three variables being a change in heart rate before and after CT removal, oxygen saturation, and respiratory rate).	The rate of pneumothorax after CT removal was 1.7% (N = 1; 95% confidence levels: < 0.01%, 9.7%). The NP investigator did not recommend a CXR based on the assessment findings for any subject after CT removal, and no children developed a pneumothorax that required reinsertion of a CT. However, a small, 2-mm, clinically insignificant pneumothorax developed in one	Additional research is needed before recommending a change in practice.	8/8

					child; this pneumothorax was found on a CXR, and no treatment was required.		
Title: Thoracostomy tube removal: Implementation of a multidisciplinary procedural pain management guideline Aim: To develop and implement a clinical practice guideline for the provision of optimal analgesia during removal of thoracostomy tubes in paediatric postoperative cardiothoracic surgery patients.							
Ring, L.M., Watson, A. (2017)	United States of America	Nonexperimental design.	50 registered nurses from one acute care children's inpatient facility.	Knowledge test, satisfaction survey, procedural note compliance scores, review of clinical notes, clinical practice guideline for thoracostomy tube removal (procedural pain management, cardiovascular surgery, electronic health record, intravenous, nurse practitioner, by mouth, registered nurse).	There was a significant increase in nursing knowledge related to clinical practice guideline education and implementation. Documentation and feasibility of the new guideline is demonstrated.	Providing staff with a clinical practice guideline based on evidence and available resources targeted to optimising procedural pain management	8/8
Title: Variability in paediatric cardiac postoperative chest tube management Aim: To explore whether there is ongoing inter-and-intra-centre variation in the management of postoperative chest tubes in paediatric heart centres.							
Taylor, A.C., Bates, K.E., Kipps, A.K. (2018)	United States of America	Descriptive study.	28 Paediatric Acute Care Cardiology Collaborative centres.	17-item survey included questions on management strategies for univentricular versus biventricular repairs, criteria for removal and evaluation after removal.	24 centres (85%) have a defined chest tube management strategy, whereas 4 centres (14%) did not. Unique management strategies for patients with univentricular versus biventricular circulation were reported by 7 centres (25%), whereas a single chest tube removal strategy for all patients	Further research is required to generate a reproducible model for collaborative multicentre quality improvement efforts across critical and acute care teams.	3/8

					was endorsed by 16 (57%). An additional 6 centres used different management strategies depending on attending and practitioner-to-practitioner. Of the 24 centres that have a defined management strategy, only 9 have documented these protocols in writing.		
Title: Are routine chest X-rays following chest tube removal necessary in asymptomatic paediatric patients? Aim: To determine if routine chest X-rays performed after chest tube removal in paediatric patients provide additional benefit for clinical management compared to observation of symptoms alone.							
Kanamori, L.M., Guner, Y., Gibbs, D., Schomberg,, J. (2021)	Unites States of America	Retrospective chart review.	116 chart reviews of children <18years who had an inpatient stay, had a CT(s) placed or managed, and removed by the paediatric surgery team between July 2017 to May 2019 from one hospital.	Patient clinical and demographic characteristics (the indication for CT, type of CT, whether CT was clamped prior to removal, whether a post-pull CXR was performed and if so, why and what were the results, whether the patient developed respiratory symptoms (e.g., tachypnea, increased oxygen requirement, shortness of breath, or chest discomfort) within 6 h after CT removal and whether an intervention was indicated after CT removal).	No patients required chest tube replacement or surgery in the absence of symptoms. Three patients exhibited clinical symptoms that would have prompted intervention regardless of post-pull CXR results. One patient had an intervention guided by post-pull CXR alone. Another patient had delayed onset of symptoms and intervention. No patients required an intervention in the group that did not have a post pull CXR.	CXR after chest tube removal is unlikely to be beneficial to clinical decision making in asymptomatic patients. Post-pull clinical symptoms can guide the clinician's decision of whether a major intervention is needed.	6/8

Title: Routine chest X-rays after pigtail chest tube removal rarely change management in children Aim: To explore if CXRs obtained following removal of pigtail chest tubes would not change the management.							
Theodorou, C.M., Hegazi, M.S., Moore, N. M., Beres, A.L. (2021)	United States of America	Retrospective cohort study.	123 chart reviews of patients <18 years old with pigtail chest tubes placed between 20142019 at one tertiary paediatric hospital.	Data were collected by identifying in the electronic medical record using CPT codes, ICD codes and by querying nursing flowsheets for thoracostomy tubes. Individual chart review was performed to identify patients who had a pigtail tube placed. Data collected included: demographic information, indication for chest tube, chest tube size, laterality, hospital location for placement, role of person placing the chest tube, complications, CXR findings after removal of a pigtail chest tube and unplanned chest tube reinsertions.	Of the 123 pigtail CT insertions 12 patients had bilateral chest tubes. Indications were pneumothorax (n = 53), pleural effusion (n = 54), chylothorax (n = 6), empyema (n = 5), and hemothorax (n = 3). Post-pull CXRs were obtained in 121/123 cases (98.4%). The two children without post-pull CXRs did not require chest tube reinsertion. Two patients required chest tube reinsertion (1.6%), both for reaccumulation of their chylothorax. No children had immediate interventions as a result of the post-pull CXR alone.	Imaging following chest tube removal may not be necessary in the majority of patients in the absence of clinical indications. However, patients with a chylothorax had a higher rate of chest tube reinsertion and warrant a lower threshold for obtaining further imaging.	7/8
Title: The effect of facilitated tucking on the pain intensity induced by chest tube removal in infants Aim: To evaluate the additive effect of facilitated tucking to the use of morphine on infant pain associated at the time of chest tube removal.							
Pouraboli, B., Mirlashari, J., Fakhr, A.S., Ranjbar, H.,	Iran	Randomised control study.	60 infants (current weight was in the range of 2500 to 4000 g, infants were 1	Neonatal Pain Scale - 6 items, 5 of which are behavioural (face expression, crying, arms, legs, and consciousness)	Pain scores were increased during chest tube removal for both the intervention and the control groups. Compared with the control group, pain scores for	Further research is required to evaluate the effect of the facilitated tucking on pain induced by chest tube removal in	8/13

Ashtari, S. (2021)			to 28 days old, postoperative from open-heart surgery in which a chest tube was placed, infants no longer required mechanical ventilation. were divided 2 groups study).	and 1 is physiologic (respiratory pattern), pain intensity parameters including physiologic pain symptoms, cardiorespiratory rate, oxygen saturation percent, neonatal behavioural responses were observed and demographic data.	infants in the intervention group were less before, during, and after chest tube removal. Using the non-pharmacologic method of the facilitated tucking combined with the pharmacologic methods can have a significant role in controlling pain induced by chest tube removal in infants after open-heart surgery. The facilitated tucking position supports the infant's body and can, therefore, be effective in his or her coping with pain and stress in procedures like chest tube removal that inducted pain in infants.	preterm infants. Preterm infants may respond differently to pain.	
Title: Clinical descriptors of pneumothorax following chest tube removal in paediatric cardiac surgery Aim: To describe the frequency of pneumothorax after chest tube removal in paediatric post-operative cardiac surgical patients and to describe the patient and clinical characteristics of those patients who developed a clinically significant pneumothorax requiring intervention.							
LaGrasta, C., Mclellan, M., Connor, J. (2021)	United States of America	Retrospective chart review.	11,651 paediatric post operative cardiac surgical patients < 18 years old clinical notes were reviewed after chest tube removal from one hospital.	Data were collected by identifying in the electronic medical record any patients that exhibited or reported any changes in baseline clinical signs or symptoms after the chest tube was removed up until the post-removal chest radiograph was obtained. Demographic data	Of the 11,651 chart reviews 25 patients were diagnosed with a pneumothorax by chest radiograph following chest tube removal (0.2%). Of these 25 patients, 15 (1.6%) had a clinically significant pneumothorax and 8 (53%) did not demonstrate a change in baseline clinical status or require an increase in	The development of criteria, based on clinical characteristics, for patients who are at increased risk of developing a pneumothorax and would require a routine chest radiograph following chest tube removal.	5/8

				included the age at the time of surgery, history of prematurity, gender, body surface area, primary cardiac diagnosis, presence of non-cardiac anomaly(s), surgical procedure, prior cardiac surgery, Risk-Adjusted Congenital Heart Surgery1 Category, and required intervention(s) to treat a pneumothorax post-chest tube removal.	supplemental oxygen, 14 (93%) required an intervention, 9 (60%) were <1 year of age, 4 (27%) had single ventricle physiology and 5 (33%) had other non-cardiac anomalies/genetic syndromes.		
Title: Adverse events related to thoracentesis and chest tube insertion: evaluation of the national collection of subject safety incidents in Japan Aim: to compile the epidemiological data on accidents involving thoracentesis and chest tube insertion. A secondary aim was to determine the risk factors for a fatal adverse event.							
Kamio, T., Iizuka, Y., Koyama, H., Fukaguchi, K. (2022)	Japan	Retrospective data review.	Japan Council for Quality Health Care open database reporting adverse events associated with thoracentesis and chest tube insertion between January 2010 and April 2020.	Data collection included all events related to thoracentesis and chest tube insertion, and a free text search was conducted to identify procedure specific events, such as pneumothorax, bleeding, haemothorax due to perforation of an intercostal artery, and cardiogenic shock in response to compression of a chest tube. The level of harm was classified as low potential for residual	137 adverse events were identified due to thoracentesis or chest tube insertion. At least 15 fatal adverse events and 17 cases of left/right misalignment were reported. Resident doctors and physicians with 10 years or more of clinical experience were mentioned in the reports. The most common complications due to adverse events were lung injury (55%), thoracic vascular injury (21%), and liver injury (10%). Surgical treatment was required for 43 (31%) of the 137 cases, and the	Care should be taken to avoid thoracic vascular injury during chest tube insertion and that immediate intervention is required should such an injury occur.	8/8

				disability, high potential for residual disability, event resulted in death or unknown.	mortality risk was significantly higher for thoracic vascular injury than for other complications (p=0.02).		
CHD congenital heart disease, CPT current procedural terminology, CT chest tube, CXR chest X-ray, ICD internal classification of disease, mm millimetre, NP nurse practitioner, 6h 6 hours							

4.1.4 Table 4: Thematic Analyses

Theme	Sub Themes	Categories (number of codes)	Exemplar
Disparity in healthcare professionals' knowledge and practice with UWSCD management	Healthcare Professionals	Discipline and Context (n=4)	*'The majority were inserted by a paediatric intensivist (n=43,35%), followed by paediatric surgery and trauma surgery (n=8, 14.6% each), and cardiothoracic surgery and interventional radiology (IR) (n=16, 13% each). The remainder (n=12) were inserted by providers in the emergency department (n=3), neonatal intensive care unit (n=2), adult cardiothoracic surgery (n=1) or at an outside hospital (n=4). In two cases this information was not reported'* (Theodorou et al. 2021) (p.2.)
		Knowledge (n=10)	*'While most nurses displayed a good knowledge of intra-pleural pressure (95%, n=115 answered correctly) and the indications for chest drain insertion (83%, n=100 answered correctly) and sites for chest drain insertion (75%, n=91 responded correctly), respondents showed a knowledge deficit regarding the anatomical principles of the lower respiratory tract; almost half of the respondents (48%, n=58) incorrectly or failed to respond to the false statement 'Intrapulmonary pressure is the pressure in the parietal cavity'* (Magner et al., 3013) (p. 2918).
		Education (n=4)	*'Notably, 62% (n=75) of nurses reported discussion with colleagues as the predominant method of keeping abreast of updates in chest drain management, while 22% (n=27) of surveyed nurses engaged in workshops and conferences as well as discussion with colleagues'* (Magner et al., 2013) (p. 2919).
	Practice Considerations	Indications (n=5)	*'The most common indication for chest tube placement was pleural effusion (n=56, 45.5%), followed by pneumothorax (n=53, 43.1%), chylothorax (n=6, 4.9%) and hemothorax (n=3, 2.3%)'* (Theodorou et al., 2021) (p. 2).
		Chest Drain and Tubing Characteristics (n=6)	*'The type of CT inserted was categorised into surgical tube (e.g., placed in the operating room with thoracoscopy) or pigtail tube (e.g., placed in the ICU, emergency department or interventional radiology)'* (Kanamori et al., 2021) (p. 632).
		Management (n=13)	*'Respondents demonstrated inconsistencies regarding the removal of chest drains, with well over half of the respondents (63%, n=76) indicating chest*

			drains should be removed during inspiration. This reflects a lack of consensus regarding this area of practice consistent with the literature' (Magner et al., 2013) (p. 2918).
		Assessment and Diagnostics (n=20)	*'Regarding practices associated with chest tube removal, 25 centres (89%) routinely obtained chest radiographs immediately before removal'* (Taylor et al., 2018)(p.1473)
	Adverse Events	Complications (n=27)	*'There were 17 cases of left/right mis-alignment during a procedure; three of these occurred during thoracentesis and 14 during chest tube insertion'* (Kamio et al., 2022) (p. 983).
		Interventions (n=12)	*'Of the patients requiring intervention, eight patients (53% of this group) did not exhibit a change in clinical status or required increased supplemental oxygen; 5 (33%) had a changed respiratory exam; and 7 (47%) had increased oxygen requirement'* (LaGrasta et al., 2021) (p. 122).
CT chest tube, ICU intensive care unit, IR interventional radiology			

4.2 Face to Face Interviews

4.2.1 Interviews Results

Ten healthcare professionals were invited to participate in a face-to-face interview that included 12 open-ended questions, seven participants consented (response rate 70%). This included five female and two male healthcare professionals of various disciplines and levels of expertise with the majority being from a nursing perspective (n=4). The level of healthcare experience ranged from 2 to 29 years with all participants having had no specific/standardised training in the management of UWSCDs (Table 5).

4.2.2 Findings

The responses from the seven healthcare professionals generated one theme (a gap between theory, guidelines and practice of UWSCD management), four subthemes (management, practice considerations, scope of practice, current practice), eleven categories, 121 codes and included 413 findings (Table 6).

A gap between theory, guidelines and practice of UWSCD management

The main theme was derived from the fact that the management, practice considerations and scope of practice for UWSCDs was not guiding current practice. There appeared to be a gap between theory, guidelines and the reality of practice with UWSCD management in the hospital. The participants were aware of the indications for UWSCD insertion/removal however not every participant was clear on the care delivery, and the knowledge, expertise, or competence required.

Management

The sub-theme management included two categories (collaboration, care delivery), 41 codes and 118 findings. Collaboration referred to the consultation process that participants described as important that occurs between the family, doctors and nurses *'medical consultation, multidisciplinary collaboration and family involvement'* and how *'teamwork'* and *'nurse cohesiveness'* with iterative *'problem solving'* was needed to build a positive *'rapport'*, *a*nd *'patient experience'*. Multidisciplinary collaboration included input and discussions between the family, patient, doctors, nurses, radiologists and play specialists such as *'discussions beforehand, prepping them, hospital play specialist input'* and a *'combined effort from the surgical and nursing staff*'. Despite many of the nurses stating that involvement with family was important one doctor stated that involving parents in the decision-making process was sometimes not helpful. *'The parents are informed of the process and again they are involved as appropriate, sometimes helpful sometimes not helpful'.* (Participant 4)

Care delivery was reported as being undertaken within a *'holistic care/approach'* that included *'hourly observations of the chest drain, that includes exit site to drain – full check, making sure you don't see any eyelets, making sure that dressing is all intact and airtight'*, *'monitoring fluid levels'*, '*monitoring air',* checking the *'tubing is secured'* and *'not kinked'*, and that *'drains are connected'*. This also included *'documentation'*, and further diagnostics such as *'interventional radiology'*, and interventions such as *'dressings'*, *'clamping'* and *'suctioning'* with ongoing assessments for *'comfort cares'*, *'pain assessment'* and distraction strategies such as '*play therapy'*. It was evident that the use of diagnostics in the management of UWSCD was variable throughout the hospital as some participants stated an x-ray was required post removal such as '*post op chest x-ray is necessary'*, others stated this was not required '*we normally don't do routine removal post chest drain x-rays unless there is a clinical indication'* and some did not know.

'I have a suspicion that we used to do routine x-rays for all patients following chest drain removal, a couple of hours post removal. I think that might of changed, we only do if clinically indicated'. (Participant 5)

There was inconsistency reported by all the participants with the exact requirements for care delivery, for example whether recording vital signs every 15 minutes *'frequent observations that need to be done, maybe 15 minutes or so'* or hourly *'hourly observations of the chest drain, that includes exit site to drain full check, making sure you don't see any eyelets, making sure the dressing is all intact and airtight'*. Some participants reported that they were unsure of the exact observation intervals, stating *'if I'm honest, I'm not quite sure. Observations might be doable hourly.'* There was however consistency in the answers from the participants with the general monitoring requirements as opposed to the exact measurements and timing of these measurements. For example, for CYP with UWSCDs all participants identified that regular observations were required including vital signs, site checks, output measurement including whether the output is air or fluid. It is also of significance to note that only the PICU nurse identified auscultation as an important assessment.

'So, completing observations and thorough respiratory assessments. Auscultating their chest at least 4 hourly to monitor for any changes. Particularly in children that have a pneumothorax.' (Participant 2)

In addition, there were variances reported in what forms were used or how these observations were recorded and by whom within the various wards such as recorded on a paediatric early

warning score chart *'Sats monitoring etc. doing hourly PEWS score for at least 4 hours'*, chest drain chart *'we have 2 x forms. 1x form where you can put L) & R) chest drains on', 'there is a chest drain chart in the notes filled out by the nursing team'* and fluid balance chart *'we consider their overall fluid balance'* where you can document the accumulative total. Securing the chest drain and having a good seal was identified as important by the participants including using strategies such as double taping *'we've double taped it so it doesn't come out'* and that the drain should be monitored at the site, checking the dressing is intact *'check the site, make sure that the dressing is intact'* and checking for any air leaks or kinking.

'*You're checking the site, to ensure there is a good seal, that there is no excessive leak or fluid leak or air leak at the site. That there is no kinking of the tubing and that things are actually coming out.'* (Participant 2)

Interestingly those that identified the dressing and site check as important were nurses whereas one doctor stated that it was the nurses' responsibility to check the dressings and UWSCD.

'The nurses look after them again, checking dressings, connections, outputs, bubbling, manage the suction and what not'. (Participant 4)

Pain assessment, distraction strategies and comfort cares were reported by all participants as an important component of UWSCD management *'you're wanting to assess pain as well and making sure they have adequate pain relief'* so children can continue with their normal activities such as play and mobilisation *'you want to mobilise the patient as well'* and the importance of including a play therapist *'play specialists, adequate pain relief for the child'*.

Practice Considerations

The sub-theme practice considerations included three categories (indications, insertion-removal, adverse events) 20 codes and 102 findings. All participants were able to identify the various indications for an UWSCD insertion being either, *'acute and operative,' 'pneumothorax,' 'haemothorax,' 'pneumonia's, empyema's, trauma'*, *'pleural effusions,'* '*chylothorax*,' or inserted *'after or during every surgery (thoracic surgery)'*.

'*Where you need to maintain the pressure but remove fluid or air from the chest would qualify for a underwater seal chest drain. Pneumothorax, haemothorax. If you want to make sure it is a sealed system and reinflate the lung.'* (Participant 3)

The participants reported a sound knowledge on the indicators for removing an UWSCD being due to *'reduced output or no output'* of *'4ml/kg', 'stable observations', 'the lung has expanded on chest X-ray', 'the patient is saturating well'* and/or the '*bubbling has stopped'*. Knowledge on the need to re-insert an UWSCD was further evident amongst the participants as being due to the *'drain not working', 'being misplaced', 'tube is blocked', 'occluded'* or '*come out or half come out'*.

'Not be draining the appropriate thing that they need to be draining. In which case we would take that drain out and put another drain in.' (Participant 4)

The insertion of a chest drain was not something that was covered in detail, this may be because most of the participants were nurses. Chest drains are predominantly inserted by a surgeon or interventional radiologist in the '*operating room by the surgical team'* and *'some done in the emergency department.'*

'By in large will be consultant or by fellow and non-training registrar in consultation with the consultant'. (Participant 6)

It was evident that the approach undertaken in the removal of UWSCD was different within the various wards as in PICU, nurses team up with a more experienced nurse to remove an UWSCD, *'it is always a double nurse thing you would always team up with someone that is more experienced in doing it'* whereas on the surgical ward '*the removal of the drains is done by a medical staff member'* usually by *'a surgical registrar often a junior surgical registrar based on their experience'* whereas on the cardiac ward or PICU the '*nurses do it.*' The decision-making process for UWSCD management and removal was ultimately reported as a senior medical officer/consultant decision with junior doctors seeking advice and guidance from their seniors. However, it was abundantly clear from the participants' responses that UWSCD removal was something that could be done by nursing staff.

'I think nursing staff do a lot of drain removals and similar things. I have seen nurses across both countries do it, including other areas other than the ward. People who care for drains everyday can definitely do a simple drain removal.' (Participant 4)

Potential adverse events included the chest drain being *'blocked'*, *'not working,' 'the drain bubbling when there was no initial pneumothorax', 'the drain being put into a fistula and causing*

more irritation or bubbling', 'shortness of breath', 'chest pain', 'desaturations', an increase in *'work of breathing', 'accumulation of fluid or air', 'lung collapse', 'increased oxygen requirement'* and *'an air leak'.* An adverse event can lead to a drain needing to be reinserted or repositioned. Multiple participants recognised the high risk associated with UWSCDs, whether that be with the management, insertion or removal.

'*You'd also remove it if it is blocked or not working, and you've not been able to fix it. They may need reinsertion or just monitor and see how they go. If it's not in the right position as well, sometimes that can be quite dangerous so it would probably need to be removed or repositioned in theatre or interventional radiology.'* (Participant 2)

Scope of Practice

The sub-theme scope of practice included three categories (guidelines, knowledge, demographics) 36 codes and 124 findings. Guidelines referred to what guides practice, the participants identified these as *'a protocol online,'* as well as suggesting a need for *'competency checks,' 'standardisation'* and *'consistency'* of care. Each participant was able to identify that there was some form of policy/guideline/protocol that existed for the management and removal of UWSCDs.

'There is a straightforward protocol to follow, and we have a good supportive team here to help educate people to do that but how we decide that is not always standardised.' (Participant 4)

However, it was evident that despite the existence of these guidelines or policies there still appeared to be inconsistencies in practice and a need for more standardisation across the hospital.

'Different people do different things.' (Participant 6)

There were also suggestions made by various participants on how improvements could be made such as *'reviewing the policies', 'standardisation', 'escalation pathways', 'supervision', 'education',* '*rigid policy'* and *'support from the doctors.'*

'But I think there would need to be an escalation process in place, if something went wrong, is there someone available that can attend. Who do you contact, what do you do.' (Participant 2)

Knowledge refers to the '*expertise of the medical and nursing staff*' including *'education'* they have received, their *'current knowledge'* or *'lack of knowledge.'* An example of *'lack of*

knowledge' was when several participants could not identify the exact recommendations for post UWSCD removal monitoring.

'There will be a frequency of obs to begin with, it probably fades with time but I don't know what that is,' (Participant 1)

There appeared to be no standard training or education for nursing or medical staff despite the nurses requesting it. The *'see one/do one'* approach seemed to be something that was applied to practice in both the medical and nursing fields and there was no specific certification or training and if there were the participants were unaware of this.

'It would be quite cool to have a chest drain management PVG. Oh god I hope there is not one. Is there one? Or something similar.' (Participant 2)

It appeared education for the nursing staff was from *'senior colleagues'*, *'surgical condition study days'* or *'learning resources'* called *'subspecialty learning continuums.'* The subspecialty learning continuum is specific to the cardiac ward, which has a *'skill validation sheet, which is part of the application to practice activity'.* There was also concern reported over the lack of experience, skill mix, patient to staff ratio and high acuity on the ward that impacted on the nurses' ability to safely care for CYP with an UWSCD.

'I know there have been situations where there has been multiple patients with chest drains on the ward and you don't always have the right number of well trained nurses caring for them. You might have someone caring for them that maybe cared for the odd stable one, now caring for a chest drain in an unstable child.' (Participant 2)

The participants also identified that regular exposure to UWSCDs increased their confidence and those who had more experience in caring for an UWSCD were more likely to have greater expertise.

'I wonder if this question is alluding to often that can be problematic as often the nurses are more experienced. The nurses are involved as well as the play therapists and probably seen a lot more than the junior registrars who have not done it.' (Participant 4)

Demographics refers to the *'patient characteristics,' 'acuity', 'age', 'patients' size'*, '*patients' physiology'* and *'patient status'* all of which could influence care delivery and *'scope of practice*

for all health professionals.' Only three participants acknowledged that despite monitoring the status of the child, one needed to view the child from a wider lens and whether the child was *'stable or 'unstable'* which inadvertently influenced where the child was placed on the ward. *'Looking at a bigger picture, not just the chest drain management. Like the overall status of the child'* (Participant 2)

Current Practice

The sub-theme current practice included three categories (reality, ability, context), 24 codes and 69 findings. Reality refers to the actual management of UWSCDs within practice including available resources such as *'emergency equipment'*, *'availability of doctors', 'when and how they are downgraded',* the need for *'staff to assist in other areas'* and how many children were being nursed within the '*Intensive Observation Area or on the ward'* (IOA).

'What affects our ratios is whether they are an IOA patient or not.. So, if you had that IOA patient that was post PICU and they had drains, they would be nursed 1:2, but if that patient then downgraded and moved to the floor, still had the chest drain but were stable then the nurse would have 3.' (Participant 5)

In addition to this the participants wanted the '*nursing hierarchy'* to value upskilling staff within the various areas where CYP with UWSCDs were being cared for.

'Unless the nursing hierarchy felt that actually in terms of workload, intensity of working in different units, different wards should be upskilled with chest drains. I would be open to that.' (Participant 6)

Ability included the staff's reported degree of *'confidence and competence',* and whether they felt *'comfortable in under water seal drain management'* were *'well supported',* and *'familiar with under water seal drains'*, or felt *'fearful and unprepared'*.

'It is getting better; we are getting more people. And I think if we have someone that is comfortable, well supported to remove the drain in a timely matter is the ideal situation. The nurses are the ideal place for that, with our support.' (Participant 4)

The participants reported the importance of feeling confident in the staff's ability in managing

UWSCDs and that one needed to be proactive and question peoples' ability in UWSCD management.

'I'm going to take that chest drain out." I don't think everyone would actually question him and everyone would say "have you taken one of these out? Have you read the policy? Do you know what's happening?" Normally you or I would flag that first and know which of our staff have done that. And no different than a Reg, sometimes a Reg has never done it before. Or doesn't have good rapport with kids as well.' (Participant 7)

Participants further identified that CYP with an UWSCD should be cared for in a surgical ward as the nurses in non-surgical areas may be *'unfamiliar with under water seal drain management'* and that *'if they are only put on wards that are able to manage and everyone is comfortable then I think that is the safest place.'* However, one participant despite 22 years of surgical nursing experience stated *'I don't feel completely confident in chest drains'* and was '*ambivalent'* to where patients with an UWSCD should be placed. However, the majority of participants stated that those with UWSCDs should be placed in an area where staff feel comfortable to care for them.

The participants reported various levels of experiential knowledge to where children with an UWSCD had been placed within the hospital such as the *'oncology ward', 'medical ward', 'surgical ward',* '*intensive observation area'*, *'PICU'* and *'NICU'*.

'Surgical wards, I guess on the other wards, but I haven't really seen any on other wards. I guess maybe on the oncology ward and of course PICU. They might remain there for some time before coming up to the ward. Maybe on the medical wards, but I think its maybe surgical wards.' (Participant 3)

However, one participant stated that it had become the culture within the hospital that when a UWSCD is inserted the patient is transferred to a surgical ward whereas another participant suggested that *'in an ideal world, I would've thought that a respiratory ward could manage them.*' It was evident amongst the responses that even if a patient was transferred to a surgical ward for UWSCD care the medical team were still consulted.

4.2.3 Table 5: Healthcare Participants' Characteristics

Participant	Discipline	Experience	Gender	Highest Degree Attained	UWSCD Qualifications	Further education
1	Registered Nurse	7.5 years	Female	PgDipHSc	Nil	Surgical conditions study day
2	Charge Nurse	8 years	Female	PgDipHSc	Nil	Competency included in PICU orientation
3	Paediatric Surgical House Officer	2 years	Male	MBChB	Nil	Diploma in Paediatrics
4	Paediatric Surgical Fellow	12 years	Female	FRACS	Nil	Nil
5	Nurse Specialist/Nurse Educator	7 years	Female	PgDipHSc	Nil	Nil
6	Paediatric Surgery	29 years	Male	MBChB MD	Nil	Nil
7	Registered Nurse	22 years	Female	PgCertHSc	Nil	Surgical conditions study day, Atrium representative training
FRACS Fellow of the Royal Australasian College of Surgeons, MBChB Bachelor of Medicine and Bachelor of Surgery, MD Doctor of Medicine, PgCertHSc Post Graduate Certificate in Health Science, PgDipHSc Post Graduate Diploma in Health Science, PICU Paediatric Intensive Care Unit						

4.2.4 Table 6: Thematic Analysis Participant Responses

Theme	Sub-Themes	Categories (number of codes)	Exemplar
A gap between theory, guidelines and practice of underwater seal chest drain management	Management	Collaboration (n=14)	*'Our surgical team are quite engaged with telling us if they want a drain kept in longer.'* (Participant 5) *'There will be exceptional circumstances, but I imagine that the nursing team on the ward may be consulted'* (Participant 6)
		Care delivery (n=27)	*'I think the chest drain is inspected for leaks and integrity, fluid leaks, wound is checked and recordings of suction on the wall and suction on the chest drain, whether there is bubbling, swinging, fluctuation and the fluid output over the 24-hour period.'* (Participant 6) *'You would monitor the site as a nurse, making sure that the dressing remains in place. That there is no excess leakage of fluid or air bubbling.'* (Participant 2)
	Practice considerations	Indications (n=8)	*'Because of the risk of inflammation and also particularly for our Fontan patients, have a risk of developing a chylothorax.'* (Participant 5) *'There are operative ones that are any of the thoracic surgical operations, either thorascopic or open generally get a chest drain, anywhere from lung biopsies to VATS to lung resections, oesophageal fistula repair. Pretty much any thoracic operation.'* (Participant 4)
		Insertion-removal (n=6)	*'Cut the retaining stitch, chest drain comes out in one move, pinch the skin or get an airtight seal, an opsite or something like that'.* (Participant 6) *'They would often be the person holding the skin, the person learning would be the person pulling out the drain and tying the purse strings. So that leaves the experienced nurses a bit more free if anything was to go wrong.'* (Participant 2)
		Adverse events (n=6)	*'They are a little bit higher risk than other patients for things like infection, air leaks, issues with the drain being pulled out or misplaced, then needing acute chest x-rays.'* (Participant 3) *'If they are bubbling, it means there is an air leak in your drain connection.'* (Participant 4)

	Scope of practice	Guidelines (n=14)	*'There is a clear guideline around it and on top of that we've got a few extra pieces that fit into pathways.'* (Participant 5) *'There is a straightforward protocol to follow, and we have a good supportive team here to help educate people to do that'* (Participant 4)
		Knowledge (n=18)	*'I know the new graduates go through a rigorous and standardised education programme. We have educators and a good group of senior nurses.'* (Participant 4) *'if we had that training to do that, we would get a better understanding of why we are doing what we are doing and how we are doing what we are doing'* (Participant 7)
		Demographics (n=4)	'*Depends on the age, if it is a baby or toddler who can't regulate their breathing voluntarily then you would do it based on how you see their breathing.'* (Participant 3) *'I think that it's depending on the patient's size, patient's physiology and the output over a period of time'* (Participant 1)
	Current practice	Reality (n=9)	'*IOA patient that was post PICU and they had drains, they would be nursed 1:2'* (Participant 5) *'Is your environment set up appropriately to manage an emergency. Have you got all of your required equipment, working oxygen and suction.'* (Participant 2)
		Ability (n=10)	*'Nurses and doctors are capable of looking after chest drains, it's a pretty basic principle but they need to be trained and skilled appropriately and it's just a matter of familiarity, comfort and having support to do that.'* (Participant 1) *'The most scary thing for me is the house officers trying to take them out, people are taking them out who have never done it before.'* (Participant 7)
		Context (n=5)	*'Cardiac patients with chest drains are best on 23B or PICU.'* (Participant 5) *'26b possibly as they have a lot of respiratory conditions. I don't understand why they don't. Because they do surgical things and they understand the respiratory things that could go wrong as well.'* (Participant 7)
IOA Intensive Observation Area, PICU Paediatric Intensive Care Unit, VATS Video-assisted Thorascopic Surgery			

Chapter Five: Discussion/Implications/Conclusion

5.1 Discussion

The purpose of this study was to investigate the knowledge and perceptions of healthcare professionals on the management and removal of UWSCDs at a large children's hospital in New Zealand as well as review the latest peer reviewed empirical literature available on this phenomenon. The literature review generated an overarching theme being 'disparity in healthcare professionals' knowledge and practice with UWSCDs' while the interviews with seven healthcare professionals generated the theme 'a gap between theory, guideline and practice of UWSCD management.' The findings generated from the interviews with healthcare professionals interestingly reflected similar findings evident in the literature review that included international peer reviewed empirical research. It was evident in this study that healthcare professionals within different disciplines, contexts and countries were required to have sufficient knowledge and expertise to be able to care for CYP with UWSCDs. In addition, the risk associated with the management and removal of UWSCDs and potential risk for adverse events or need for further interventions is high, if the care provided is inadequate.

It was evident with the healthcare professionals interviews that CYP with UWSCDs were placed in specific areas throughout the children's hospital. At present general surgical patients are placed on the general surgical ward, cardiac patients on the cardiac ward and patients requiring intensive care management are placed in the PICU or NICU depending on age. Current policy within the hospital indicates that even if a CYP has an UWSCD inserted for a medical condition, such as empyema they are automatically placed into the care of the general surgical team regardless of whether the general surgeon inserted the UWSCD (Primhak et al., 2022). It was highlighted in the interviews that there is an obvious divide as to whether this is appropriate, as once the patient is under the care of the general surgical team, they are usually required to transfer to the general surgical ward. However, there is no evidence-based research published to suggest that this is appropriate. The staff on the general surgical and cardiac ward are exposed to UWSCDs more regularly, therefore the transfer of care may be more suitable as staff may have more knowledge than those outside of these areas (Magner et al., 2013). There is obvious risk involved with UWSCDs if managed or removed incorrectly, therefore it is important for those who have greater knowledge care for these CYP (Theodorou et al., 2021). However, it is also evident in international literature and from the interviews conducted that there is a lack of knowledge around UWSCD management and removal and the current education and training for healthcare professionals is inadequate (Magner et al., 2013; Seyma et al., 2021).

It is apparent a knowledge deficit exists with the management and removal of UWSCDs in CYP, as was highlighted in the literature and in the interviews undertaken. Magner et al (2013) reported that those who had more exposure to UWSCDs had greater knowledge and expertise around the management and day-to-day cares than those who had less exposure. For example, those in management roles had less exposure and therefore less knowledge of UWSCD management and were at a higher risk of providing inadequate/unsafe care (Magner et al., 2013). However, the results from the interviews were not necessarily reflective of this as only those who had exposure to UWSCDs in the children's hospital were interviewed. Despite this, it was evident in the interviews that a knowledge deficit did exist amongst the healthcare professionals even with regular exposure. A knowledge deficit also existed in adult settings as Kesieme et al (2016) stated nurses' knowledge of UWSCD care was insufficient and highlighted an urgent need for UWSCD education and training to help improve this knowledge gap (Kesieme et al., 2016). It is reported in the literature that regular in-house workshops or educational programmes are known to be successful in improving nurses' knowledge on UWSCD management and regular educational updates is important for maintaining knowledge (Bedier, El-Ata, & Ibrahim, 2016; Ring & Watson, 2017).

It was evident in the interviews there was significant variation in UWSCD management and removal educational opportunities a healthcare professional received in the children's hospital including variation on what defined a trained professional. International literature highlights that education for healthcare professionals for UWSCD management and removal includes practice guidelines, in house workshops and being cognisant and up to date with the state of the science in this area of practice (Magner et al., 2013; Seyma et al., 2021). However, in the children's hospital there was no specific training required for a nurse to be able to care for a patient with an UWSCD, which is concerning as it is important that nurses have adequate knowledge and are able to identify complications associated with UWSCDs early to prevent adverse events (Kamio et al., 2022; Kanamori et al., 2021; Theodorou et al., 2021). In addition, the area in which a nurse works also determines whether they can be trained to remove UWSCDs (Hutching & Sanchez, 2020).

The 'See one, do one' approach is considered to be the standard approach within the children's hospital; however, this appears to be an outdated unsafe practice and is often cited in older healthcare literature (Rodriguez-Paz et al., 2009). Of interest, Ho et al (2021) found that a mobile application was effective in training nursing students to be more efficient with clinical reasoning and self-directed learning for UWSCDs (Ho, Chiu, Li, Huang, & Cheng, 2021) whereas Basler and Englund (2020) found that simulation also improved nursing students' knowledge for UWSCD management. These studies provide some ideas for educational and training workshops

for healthcare professionals that could be beneficial to use at the children's hospital in New Zealand.

A more standardised policy or guideline is recommended to provide consistency in care (Seyma et al., 2021). It is concerning to note that despite there being very clear guidelines that state the required management for UWSCDs, there continues to be uncertainty regarding what is required in clinical practice (Hamer & McCarthy, 2021; Hutching & Sanchez, 2020; Newborn Services Clinical Practice Committee, 2018; Primhak et al., 2022). The healthcare professionals at the children's hospital were uncertain about the frequency of vital signs, emergency equipment and the exact monitoring or documentation required. Another significant finding was that the documentation was different for UWSCD monitoring and output within the different areas in the same hospital. Of interest, Magner et al (2013) stated that only a mere 27% of participants utilised clinical practice guidelines as their primary source of information. There are many benefits reported in following clinical practice guidelines and/or protocols for the management of UWSCDs in CYP as protocol-based management can help reduce the length of time an UWSCD is in place, reduce hospital length of stay as well as reduce the risk of adverse outcomes (Oberoi et al., 2020). Ring and Watson (2017) proved that implementation and education of a clinical practice guideline enhanced nursing knowledge. It would be beneficial to embed clinical practice guidelines into UWSCD educational programmes at the children's hospital as this would make healthcare professionals more aware of the technicalities that exist for the management and removal of UWSCDs.

UWSCD removal is a complex procedure that has many associated risks, such as developing a pneumothorax (LaGrasta et al., 2021; Theodorou et al., 2021; Woodward et al., 2013). In the children's hospital it was reported that a trained cardiac, ICU nurse or doctor could remove an UWSCD whereas a nurse on the ward could not. The doctors/surgeons stated that they were on a rotation roster, so the expectation for them to be proficient in UWSCD removal was an unreasonable and unobtainable goal. The general consensus from the healthcare professionals was that if a ward nurse received adequate UWSCD removal education and had enough experience in caring for CYP with UWSCDs, then nurses should be able to remove an UWSCD on the ward. Sadly, Magner et al (2013) identified that a significant percentage of participants in their study perceived that UWSCDs should be removed on inspiration. It is known that removing an UWSCD on inspiration leads to a pneumothorax as the patient breathes air into the pleural space through the chest drain site (Theodorou et al., 2021). Unfortunately, there is no specific training or competency set up for healthcare professionals within this hospital, therefore an educational training programme as well as utilisation of policy and guidelines is something that is needed.

The interviews accentuated the uncertainty as to whether a chest x-ray was required post UWSCD removal or whether chest x-rays are performed dependant on the indication for the UWSCD or area in which CYP are placed. The clinical guideline is open to interpretation, where it is suggested that a chest x-ray is done if clinically indicated or post removal chest x-ray is done prior to 1700hrs (Hutching & Sanchez, 2020). The literature highlights that this uncertainty regarding the requirement for a chest x-ray post removal exists globally (Kanamori et al., 2021; LaGrasta et al., 2021; Taylor et al., 2018). Kanamori et al (2021) reported that even though multiple centres obtain pre and post removal chest x-rays the results do not necessarily alter practice and that complications post removal were not without other changes in clinical symptoms (Theodorou et al., 2021). A systematic review reported not all patients that had abnormal chest x-rays required reintervention and those that did need reintervention also showed changes in their clinical status, yet further research is required to influence definite recommendations for clinical practice. (Sweet et al., 2021). These findings are further reflected in the literature (Kanamori et al., 2021; LaGrasta et al., 2021; Theodorou et al., 2021; Woodward et al., 2013). However, there still seems to be an ongoing debate on the benefits and/or deficits of a post removal chest-x-ray including reduced cost and exposure to radiation (McGrath et al., 2017; Woodward et al., 2013). It is reasonable to omit a post removal chest x-ray and complete only if clinically indicated, but to ensure the CYP is monitored closely and any changes in their clinical symptoms be escalated promptly, to prevent adverse outcomes as per the current UWSCD guideline at the children's hospital (Hutching & Sanchez, 2020). LaGrasta et al (2021) suggested developing criteria to identify those who are at greater risk of developing a pneumothorax and therefore require a post removal chest x-ray, this may be something to consider for future guidelines.

Healthcare professionals in this study mentioned the potential adverse events or complications of UWSCDs at the children's hospital however, this area was not covered in great detail. This may be secondary to the nature of the question and not being prompted for more information or it could be secondary to decreased knowledge around adverse events/complications at the hospital. Potential adverse events and complications such as readmission to hospital, organ damage, UWSCD misalignment, the need for ventilation, air leaks, vascular injury, surgical haemostasis, kinked or blocked tubes, pneumonia and death are very significant adverse events reported in the literature (Kamio et al.,
2022; Kanamori et al., 2021; LaGrasta et al., 2021). Literature on CYP's adverse outcomes or complications with an UWSCD reported as primary outcomes are limited as many studies identified adverse events as secondary outcomes. Kamio et al (2022) reported on multiple risks involved with UWSCD insertion, some of these being vascular injury, lung injury and liver injury.

The potential risk associated with UWSCD management and removal emphasises how important it is that healthcare professionals are competent and able to easily identify any complications or changes in clinical status sooner rather than later. This evidently links back to healthcare professionals' knowledge, if healthcare professionals have sufficient knowledge regarding the management and removal of UWSCDs, adverse outcomes could be avoided or the severity of a complication lessened (Magner et al., 2013; Seyma et al., 2021). In order to improve knowledge, adequate training and education is paramount.

5.2 Limitations and Strengths

The design and method of the integrative review allowed for a complete review of the current literature available for UWSCD management and removal in CYP where a gap in international research was identified. The data from the healthcare professionals' interviews were able to be compared to international paediatric literature on UWSCD management and removal. Another key strength is that there was a wide range of experiential knowledge in years and expertise between the doctors and the nurses which adds value and credibility to the results. There was also a nurse representative from each area being the general surgical, cardiac ward and PICU which mitigates bias based on the specific area a nurse worked.

There are several limitations to this study that warrant consideration. The interviews were conducted in one large tertiary children's hospital which may limit the transferability of findings to other hospitals in New Zealand. This study included general surgeons however, it did not include cardiac surgeons or intensivists from the NICU or PICU. It may have been beneficial to know the perceptions of the cardiologists or cardiac surgeons or intensivists as nurses in those areas remove UWSCDs in CYP. A thoracic surgeon was invited to participate however, they did not consent to participate, the reasons for non-consent would have been important to understand. There were also time constraints and limited availability of resources with this project including one person transcribing the interviews verbatim therefore the number of participants were limited, the project had to be completed within 12 months, the author was working full-time and non English language empirical literature was excluded from the integrative review. There may have been international literature available in other languages that could have provided a wider international lens relevant to the research question. Despite these limitations the procedure undertaken by the author in this project was rigorous and followed a systematic process.

5.3 Implications for Practice and Research

The clinical guidelines currently within the hospital for UWSCDs and empyema are currently relevant. It is important that these continue to get reviewed every two years to keep up to date

with the latest evidence-based research. It is recommended that the main clinical guideline *'Chest drains in children,*' be updated to include more contemporary literature. There is obviously an urgent need to review the neonatal guideline for UWSCD as this has not been reviewed since 2018. It is evident that there is limited available research undertaken on UWSCDs in neonates, therefore more research is required to provide more definitive recommendations for the neonatal guideline.

Standardising guidelines, education and training will be valuable and is highly recommended. This study highlighted a need for standardisation in care for UWSCD management and removal at the children's hospital in New Zealand. It is recommended that there is more consistency in clinical practice which will be achieved by providing education and appropriate training to all healthcare professionals caring for CYP with UWSCDs. There is an urgent need to upskill staff to become more competent with UWSCD management and removal. Recommendations for training and education include creating an educational programme, competencies, simulation and learning resources via mobile applications.

There is also an opportunity to train nurses who care for UWSCDs regularly on the general surgical ward. Training the nursing staff will provide more consistency in care, ability to prioritise and manage timing of a removal and not rely on medical team availability. A nurse should be identified as having sufficient knowledge of UWSCD management prior to caring for CYP with an UWSCD. Once they are competent with management of an UWSCD, they can then be considered for further education and assessment of competence in removal of an UWSCD.
An incidental finding in this study included the different documentation for UWSCD monitoring and output throughout the hospital. There is an ideal opportunity here to standardise the UWSCD documentation forms throughout the hospital. This will provide smoother transitions between ward areas, consistency, and standardisation for all CYP with an UWSCD. Standardisation in documentation will also support the standardisation of UWSCD guidelines, education, and training.

5.4 Conclusion

There is a lack of research for UWSCD management and removal, particularly in CYP. This study highlighted that there is a discrepancy between healthcare professionals' perceptions and knowledge of UWSCD management and removal, and what is required to manage and remove UWSCDs safely and effectively. The literature emphasised that having up to date guidelines influences adequate management and care of CYP with UWSCDs, can help reduce the length of time a UWSCD is in place, reduce hospital length of stay as well as reduce the risk of adverse

outcomes. Despite there being clinical guidelines available to guide clinical practice within a large tertiary children's hospital in New Zealand, these were significantly underutilised. This was emphasised through the healthcare professionals' inability to methodically identify recommended safe practice, inconsistencies existed dependant on illness/indication for UWSCD and the ward the patient was placed on, in the documentation, requirement for post-removal chest x-ray and also the suitability of the nurse to be trained to provide removal of an UWSCD. Based on the findings of this quality improvement project there is an opportunity to create an educational package for healthcare professionals, to advance their knowledge on UWSCD management in CYP at the children's hospital. There is also an opportunity to train more nurses to upskill them in the removal of UWSCDs and to provide healthcare professionals with the relevant education and knowledge to be able to adequately care for patients with UWSCDs and ultimately prevent adverse events.

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Appendix A

Participant Information Sheet

Date Information Sheet Produced:
30/11/2021

Project Title
Healthcare professionals' perceptions on the management and removal of underwater seal chest drains in hospital: New Zealand

An Invitation
My name is Jacqui Lawless (Morrison) and I am the lead researcher for a project being undertaken by myself at this hospital for a quality improvement initiative to complete a Masters in Child Health within the Auckland University of Technology. This study will investigate healthcare professionals' perceptions on the management and removal of underwater seal chest drains in this hospital. As a key health care professional within the health care service in New Zealand, I would like to invite you to participate in this research.

What is the purpose of this research?
The purpose of this research is to undertake a critical review of the literature on the management and removal of underwater seal chest drains. A secondary aim will be to explore healthcare professionals' perceptions and knowledge on the management and removal of underwater seal chest drains at this hospital in New Zealand. The findings from the literature review will be submitted for publication in a peer-reviewed journal however, the findings from the healthcare professionals' perceptions on the management and removal of underwater seal chest drains at this hospital will not be published. However, these findings may be presented within this hospital as a quality improvement project to further develop practice, update guidelines and educational initiatives.

How was I identified and why am I being invited to participate in this research?
You have received this invitation because you have been identified as a key healthcare professional in the management and removal of underwater seal chest drains at this hospital.

How do I agree to participate in this research?
If you decide to participate, please complete the attached consent form and let me know your availability over the next month. I will then set up a time to meet with you, to complete a half hour interview. The interview will consist of twelve questions related to the management and removal of underwater seal chest drains.
Your participation in this research is voluntary and whether or not you choose to participate will neither advantage nor disadvantage you.

What will happen in this research?
Once you have consented to be involved in this research project, a face-to-face interview will take place at a time and place convenient for all. This interview will be voice recorded and will take up to 30 minutes.

What are the discomforts and risks?
We do not anticipate any discomfort or risks to you as a participant.

What are the benefits?

The study findings can be used to develop further practice, update guidelines and educational initiatives at this hospital.

How will my privacy be protected?
No information will be collected that identifies you. The findings from the interviews with healthcare professionals will not be published. All information collected from the interviews will be kept secure.

What are the costs of participating in this research?
The only cost to you will be your time to consider this invitation and complete the interview. I anticipate the interview will take approximately 30 minutes to complete.

What opportunity do I have to consider this invitation?
You have unlimited time to consider this invitation. Please let me know via email or phone whether you would like to participate.

Will I receive feedback on the results of this research?
If you would like to receive feedback on the results of the research, I would be happy to provide verbal feedback. I can also update you on the summary of the findings once the study is complete as well as share with you the recommendations to guide further practice, guidelines and educational initiatives.

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 myself, Jacqui Lawless (Morrison). Jacqui Lawless (Morrison) hospital contact details removed to ensure confidentiality and anonymity.

Whom do I contact for further information about this research?
Please keep this Information Sheet for your future reference. You are also able to contact me using the following contact details.

Researcher Contact Details
Jacqui Lawless (Morrison). Jacqui Lawless (Morrison) hospital contact details removed to ensure confidentiality and anonymity.

Project Supervisor Contact Details
Dr Mandie Jane Foster, Senior Lecturer, Auckland University of Technology, School of Clinical Sciences, Nursing, mandie.foster@aut.ac, 09 921 9666 Ext 8468.

Appendix B

Healthcare Professionals: Consent Form

Healthcare professionals' perceptions of the management and removal of underwater seal chest drains in hospital: New Zealand

1. I ……..... of..... agree to participate in the study described in the participant information form attached to this form.
2. I acknowledge that I have read the participant information form, which explains why I have been selected, the aims of the study and the nature and the possible risks of the investigation, and the statement has been explained to me to my satisfaction.
3. Before signing this consent form, I have been given the opportunity of asking any questions relating to any possible physical and mental harm I might suffer as a result of my participation, and I have received satisfactory answers.
4. I understand that I can withdraw from the study at any time without prejudice to my relationship with this hospital.
5. I understand that the findings generated from the interviews will not be published however, they may be presented within this hospital as a quality improvement initiative. I understand care will be taken to preserve anonymity.
6. I understand that if I have any questions relating to my participation in this research, I may contact Jacqui Lawless (Morrison) hospital contact details removed to ensure confidentiality and anonymity.
7. I acknowledge receipt of a copy of this consent form and the participant information form.

_____ _____ _____

Signature of participant **Please PRINT name** **Date**

_____ _____ _____

Signature of investigator **Please PRINT name** **Date**