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The Impact of Indirect Ttransport to a Trauma Centre on Survival for Major Trauma Patients: A National Propensity-Adjusted Observational Study

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Abstract

Introduction
An optimally structured prehospital trauma care system can reduce the consequences of serious injuries. While trauma systems in some countries have adopted the policy of transporting major trauma patients directly to a trauma centre (TC) bypassing closer lower-level hospitals, other countries have been less directive in adopting this policy.

Objective
To explore the short-term survival of direct versus indirect transfer to a definitive care TC for major trauma patients injured in locations in Aotearoa New Zealand (NZ) where there was an opportunity for indirect transportation.

Methods
National administrative data from the NZ Trauma Registry and Emergency Medical Services (EMS) were linked. Major trauma patients for whom there was no hospital closer than the definitive care TC were excluded. Propensity-weighted adjusted models were used to compare mortality (2-week and 30-day) between those for whom EMS transported directly versus indirectly.

Results
Of 1,008 patients considered to have an opportunity for transfer, 370 (36.7%) were admitted at one hospital before their definitive care TC. Similar percentages of directly and indirectly transported patients died within 30 days (8.9% and 10.0% respectively; $p = 0.6$). Lower 2-week (aRR 0.64, 95%CI 0.38, 1.06) and 30-day mortality (aRR 0.70, 95%CI 0.42, 1.16) were observed for those transported indirectly. Older ($\geq$55 years) indirectly transported patients were estimated to have a 30-day mortality aRR of 0.56 (95%CI 0.30, 1.05) that of those directly transported whereas, for younger patients, the direction and strength of evidence differed (aRR 1.31; 95%CI 0.64, 2.69).

Conclusion
For major trauma patients in NZ, this study found no evidence of a statistically significant difference in short-term mortality between those transported directly and indirectly, although point estimates suggest possible lower mortality, particularly for older patients, amongst those transported indirectly. Study limitations, including wide confidence intervals, are emphasised and additional research is needed to further confirm these findings and aid in nation-specific delivery of trauma care.

Keywords
emergency medical services; major trauma; ambulance; transport pathway; population

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Introduction

Optimally structured prehospital trauma care can prevent or reduce the consequences of many serious injuries [1, 2]. In the Emergency Medical Services (EMS) phase of trauma care, structural attributes including equipment, facilities, staffing, provider knowledge base, credentialing, deployment and transport routes, can be improved to optimise clinical outcomes for major trauma patients [3, 4].

Prehospital triage by EMS aims to ensure the transportation of the patient to the right hospital at the right time [5] The direct transportation of major trauma patients to designated trauma hospitals or centres (TCs), while bypassing closer non-specialised hospitals, is considered optimal and has been shown, in some studies, to significantly reduce mortality in the US, Canada, UK, and other countries [6–9]. Difficulties in diagnosis at scene and non-adherence to major trauma destination policies add complexities when evaluating the impact of transport pathways on major trauma patients [10, 11]. Interestingly, a landmark US study observed that a larger effect of treatment at a TC was apparent for patients under 55 years of age compared to those 55–84 years old [6]. Since some studies have reported increased mortality for those transferred, there have been calls for national studies that use population-based patient registries [12, 13].

Evidence to support the time-sensitive nature of trauma care remains equivocal [14–16]. In Aotearoa New Zealand (NZ), it is estimated that 16% of the population do not live within 60 minutes of specialised trauma care [17]. Inequities in access to timely care also exist with Māori (NZ's Indigenous population) and those living rurally having poorer access [17].

The vast majority (97%) of major trauma patients in NZ arrive at hospital via EMS [18]. NZ's National Trauma Network data indicates that 20% of major trauma cases are not transported directly to definitive care [18]. Whether all major trauma patients in NZ should attend a definitive care TC directly, potentially bypassing closer lower-level hospitals, is debated and uncertainty exists as to whether direct and timely transport to a definitive care TC improves outcomes [13, 19].

This paper seeks to answer whether, among those with major trauma injured in locations where there was a lower-level hospital closer than the nearest TC, indirect transport to the definitive care TC results in different short-term survival rates than direct transport.

Methods

Setting

NZ (population ∼5 million) has two emergency road ambulance providers, Hato Hone St John (HHStJ) servicing over 90% of the population and Wellington Free Ambulance (WFA), covering the remainder. Typically, road EMS are dispatched first, followed by air EMS (typically helicopters) if required. With regard to trauma care, NZ hospitals can be categorised as: advanced (Level 1), mid (Level 2), low (Level 3), minimal (Level 4) or non-trauma, with mid and advanced levels considered specialised TCs [20]. In NZ, an advanced level trauma service is one that can provide the full spectrum of care for critically injured patients, from reception and resuscitation to discharge and rehabilitation. A mid-level service in NZ, based in either metropolitan or rural areas, should be able to provide the same clinical care as an advanced hospital, but without the same level of research and education activities. Low-level trauma hospitals, on the other hand, have the capabilities to assess, resuscitate, undertake emergency surgery and stabilise a small number of seriously injured patients, while organising transfer to a definitive care hospital, if need be. Hospitals with minimal trauma services are those considered capable of providing resuscitation and early stabilisation, with prompt transfer of major trauma patients to a higher trauma level hospital expected.

Study Population

As part of a wider project examining the effectiveness of EMS care for improving survival from major trauma in the prehospital phase, a retrospective cohort study (1 December 2016 to 30 November 2018) was undertaken [21]. This cohort included all those who experienced major trauma in NZ and were attended by EMS during these two years; it thus contained 3,333 individuals who were attended by HHStJ or WFA for an acute injury and either died prehospital, or were admitted to hospital and met the NZ Trauma Registry (NZTR) entry criteria (Injury Severity Score (ISS) >12 or died in hospital) [22].

As this study aimed to compare the survival benefit of direct vs indirect transport to a definitive care TC, those who did not attend a TC were excluded (i.e. those not transported from the scene by EMS, those who died prehospitally and those whose definitive care was not provided by a TC). Patients with substantial burn injuries were also excluded as, in NZ, there is a different destination policy for such patients as not at all TCs provide specialist burn care. Following consultation with EMS colleagues in NZ, two time-based exclusion criteria based on those used in a similar US study [12] were applied: those for whom time from EMS call to hospital was longer than 24 hours and those who died in hospital within 2 hours of the EMS call. Given the first 24 hours following injury is a crucial treatment period, the rationale for the first of these criteria is that the impact of EMS transport pathways will be harder to disentangle for these patients. In Garwe et al.'s propensity-adjusted survival analysis assessing the impact of directness of transport for major trauma patients [12], the reasons given for excluding patients that died within 2 hours of injury was that opportunity for in-hospital severity scoring was limited (compromising risk adjustment) and that the majority of these deaths were considered to be "likely nonpreventable". With the intent of restricting to patients that had an opportunity for indirect transfer, patients whose closest hospital was an advanced-level TC were excluded, as were those for whose closest hospital was a mid-level TC and the highest-level care received was provided by a mid-level TC. In line with Garwe et al. [12], patients who attended more than one intermediary hospital were excluded (these patients are likely to differ to those who attended one intermediary hospital).

Data sources

Road EMS electronic Patient Report Forms record incident details, patient status, and EMS response including prehospital time, treatment provided and destination. Incident and vehicle data from Computer Aided Despatch was also incorporated. The NZTR, a prospectively maintained database registry of major trauma patients admitted to a NZ hospital, was used to obtain information on injury severity, diagnosis, treatments, and discharge from all hospitals involved in the acute care of patients. Additional data sources included NZ's National Minimum Dataset of hospital discharges, Mortality Collection, and the National Health Index database.

Statistical Analysis

Outcome Variables

Two-week mortality was defined as death in hospital or post-discharge within 14 days from time of EMS call; similarly for 30-day mortality. Time of death was obtained from the NZTR for those who died in hospital; post-discharge date of death was obtained from the National Health Index database.

Predictor Variable

The 'definitive care' hospital was that recorded by the NZTR, reflecting the largest hospital that the patient was managed in (or the last advanced-level TC if transfer between such TCs occurred) [22]. If patients were not discharged from any hospitals before arriving at their definitive care TC, then they were classified as directly transported; remaining patients were classified as indirect.

Modelling

The analysis involved a two-step modelling process. In the first step, weights were estimated from a propensity score (PS) model; the second step involved using these weights in an analysis model. The following describes the potential confounding variables considered within each model.

Propensity Score Model

Propensity scores were obtained from a logistic regression model with directness of transport as the outcome variable; all potentially confounding variables measured prior to the transportation decision and considered to be related to mortality were included in the initial PS model. These variables included the following. Age at injury was included as a 5-level categorical variable, with stratification using <55, ≥ 55 years used to enable comparison with MacKenzie's paper [6]. Sex was included as male or female. Patients were considered Māori if any of the three recorded ethnicities in the National Health Index database were Māori.

Time of EMS call was categorised as two variables: day (6am to 10pm) vs night and weekday vs weekend. Theoretical time from location of incidence to all NZ hospitals was calculated using road network data; this included estimates of time to reach the patient, on-scene time and travel to the hospital and assumed immediate response, use of the shortest route, legal road speed, no stopping at intersections, and ideal driving conditions [17]. From this two variables were created: theoretical time to closest hospital and theoretical time to closest mid/advanced level hospital. A binary variable was also created to indicate the level of the closest hospital. The 2018 Geographic Classification for Health (GCH) was based on the incident location [23].

The time from Injury to EMS call was obtained, alongwith the EMS response time (phone pick-up to first vehicle on-scene). The 'most life-threatening events (LTE) identified at scene' were coded from clinical impressions and classified sequentially into airway, breathing, circulation and neurological difficulties, consistent with Gomes et al. [24].

Injury mechanism, as recorded by EMS on-scene, was categorised into Transport-related, Fall or Other. Other EMS variables included: dominant injury type (i.e. penetrating or blunt), despatch priority (red and purple indicate high priority), intensive care paramedic (ICP) at incident, and clinical status at scene (immediate, potential and no/unlikely Threat to Life (TTL). Initial on-scene vital signs included Systolic Blood Pressure (SBP), Respiratory Rate and the Glasgow Coma Scale (GCS).

From the initial PS model, the PS was stratified into optimal strata and the dataset reweighted to improve balance in the input variables across strata [25]. Covariate balance was assessed overall (pre and post weights) and within strata. Variables with the largest standardised differences and/or the largest variance ratios were excluded or categorised. These steps were repeated until standardised differences were as small as possible and variance ratios were close to one. The PS weights from the final model were retained to include in the analysis model.

Analysis Model

A modified generalised linear Poisson regression model with a log-link function and robust standard errors was used to estimate relative risk (RR) [26]. Crude RR estimates were produced using mortality as the outcome variable and directness of transport as the predictor variable. A more sophisticated model that included weights obtained from the final propensity score model was estimated as well as a propensity-weighted adjusted model that included potential confounding variables (see below); these models used to estimate adjusted RR (aRR) were complete case analyses (i.e. patients missing covariate data were excluded). Post-hoc analyses were undertaken to explore the impact of the propensity weights and the "opportunity for indirect" inclusion criteria.

The following potential confounding variables were not known at the time of the transportation decision and thus were not included in the PS model; instead, they were included in the analysis model. The Quan modification of the Charlson Comorbidity Index was determined using a 5-year lookback period of hospital discharge data [27]. The NZTR was the source of patients' Injury Severity Score (ISS) and Abbreviated Injury Scores (AIS). 'Intubation prior to definitive care' flags those intubated prehospitally, plus those intubated in the Emergency Department of the first hospital for those who were subsequently transported. Prehospital interventions for LTE were classified into Basic or Advanced (Supplementary Table 1). Total prehospital time included response time, on-scene time and transport time to first hospital. SBP and GCS on arrival to hospital were also included, as was primary diagnosis of injury as recorded in the NMDS.

A select number of variables from the PS model were also included in the analysis model; these were variables considered strongly related to in-hospital mortality such as age.

Results

From the cohort of 3,333, an analysis dataset of 1,008 was obtained (Figure 1). Of these, 370 (37%) major trauma patients were transported indirectly to their definitive care TC; the majority (255, 69%) were transferred from mid to an advanced-level TC, 66 (18%) from non-TC to advanced and 41 (11%) from non-TC to mid-level (Supplementary Table 2). Eight (2%) patients were transferred between advanced-level TCs for spinal or traumatic brain injury care.

Characteristics of Patients in this Study, Overall and by Transport Pathway

Patients transported indirectly were more likely to be 0-14 years (11% compared to 5% of the directly transported) and Māori (29% compared to 20%) (Table 1). For more than half (56%) of those transported indirectly, the trauma care capability of the closest hospital to the incident was mid-level, compared to 29% for those directly transported. Almost three-quarters (71%) of patients directly transported were injured in rural locations (R1-R3) compared to 47% for those indirectly transported. A higher proportion of indirectly transported patients were injured from a fall (29% compared to 16%). Interestingly, traumatic brain injury was less common among those transported directly (30% compared to 47%) as was low ISS (26% with ISS<16 compared to 14%).

Directly transported patients were more likely to have an ICP attend the incident (78% compared to 58%) despite a higher proportion of indirect patients having an on-scene clinical status of immediate TTL (direct: 17%, indirect: 33%) (Table 2). Indirectly transported patients were more likely to have a neurological LTE identified at scene (13% compared to 8%), less likely to have breathing identified as their most LTE (11% compared to 14%) and less likely to have at least one advanced prehospital intervention for their LTE (24% compared to 41%). Over half of the indirectly transported patients had no recorded prehospital interventions for LTE (51% compared to 33%) but were more likely to receive intubation prior to definitive care (28% vs 11%).

Median response time and prehospital time were both longer for those transported directly. Median total time to definitive care was close to 2 hours for those transported directly compared with almost 8 hours for those transported indirectly.

Short-term Mortality of Patients in this Study, by Transport Pathway

A similar proportion of patients died in hospital (excluding five who died within the first 2 hours; direct: 9.1%, indirect: 8.9%) although directly transported patients were more likely to die within 2-24 hours (3.3% compared to 1.4%) (Table 3). Likewise, a similar proportion of patients died within 2 weeks of their injury event (including those who died following discharge; direct: 8.3%, indirect: 8.6%). Within 30 days this was 8.9% and 10.0% respectively.

Figure 1: Flowchart for eligibility into analysis dataset

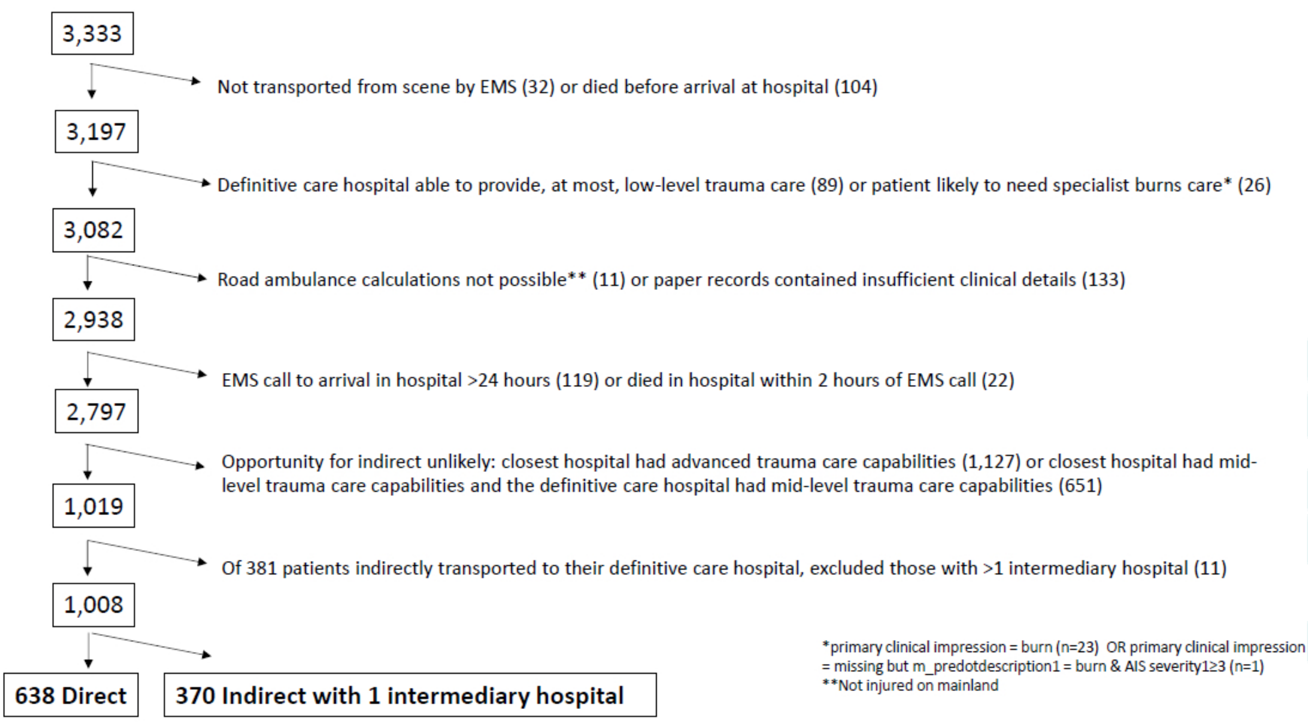


Table 1: Sociodemographic and Injury Characteristics of Major Trauma Patients by Directness of Transport to Definitive Care Trauma Centre (TC) (N = 1,008)

	Direct n = 638		**Indirect** n = 370		χ^2 **p-value**
	n	**col %**	**n**	**col %**	
Age (years)					0.03
0-14	34	5.3	39	10.5	
15-34	223	35.0	124	33.5	
35-54	253	39.7	91	24.6	
55-74	166	26.0	80	21.6	
75+	62	9.7	36	9.7	
Male	453	71.0	261	70.5	0.9
Ethnicity: Māori*	127	19.9	106	28.6	0.002
Charlson Comorbidity (Quan): ≥1*	76	12.0	54	14.6	0.2
Emergency Medical Services (EMS) Call time					
10pm-6am (vs 'day')	82	12.9	60	16.2	0.1
Weekend (vs weekday)	243	38.1	143	38.6	0.8
Injury to EMS Call >15min	52	8.2	40	10.8	0.2
Theoretical time to closest:					
Advanced/Mid-level TC hospital >60min	357	56.0	240	64.9	0.006
Hospital (any level) >60min	547	85.7	345	93.2	<0.001
Trauma care capabilities of closest hospital					<0.001
Mid-level	185	29.0	209	56.5	
Low-level	90	14.1	51	13.8	
Minimal	233	36.5	68	18.4	
Non-trauma	130	20.4	42	11.4	
Incident Geographic Classification for Health (GCH)					<0.001
U1 (most urban)	160	25.1	55	14.9	
U2	25	3.9	141	38.1	
R1	214	33.5	73	19.7	
R2	159	24.9	79	21.4	
R3 (most remote)	80	12.5	22	5.9	
Mechanism of injury					<0.001
Transport	461	72.3	205	55.4	
Fall	105	16.5	106	28.6	
Other	72	11.3	59	15.9	
Injury type: Penetrating	16	2.5	14	3.8	0.3
Primary diagnosis of injury**					<0.001
Traumatic brain injury (TBI)	193	30.3	172	46.6	
Fracture (excluding TBI)	250	39.2	83	22.5	
Spinal Cord Injury (SCI)	36	5.6	28	7.6	
Internal organ injury (excluding TBI & SCI)	121	19.0	63	17.1	
Other	38	6.0	24	6.5	
Injury Severity Score (ISS)					<0.001
<16	166	26.0	53	14.3	
16-24	296	46.4	182	49.2	
25-44	150	23.5	120	32.4	
45+	26	4.1	15	4.1	

Continued

Table 1: Continued

	Direct n = 638		Indirect n = 370		χ^2 p-value
	n	col %	n	col %	
ISS body region if AIS≥2 (y/n)					
Head/Neck	305	47.8	236	63.8	<0.001
Face	93	14.6	60	16.2	0.5
Chest	440	69.0	181	48.9	<0.001
Abdomen	264	41.4	113	30.5	0.001
Extremities	385	60.3	140	37.8	<0.001
External/Other trauma	3	0.5	2	0.5	0.9
No. ISS body regions involved (AIS≥2)					<0.001
1	113	17.7	141	38.1	
2	276	43.3	137	37.0	
3+	249	39.0	92	24.9	

*Small amounts of missingness in some variables: Māori 1; Comorbidity 3.
**Recorded at hospital discharge. Primary diagnosis was classified using the Injury Mortality Diagnosis matrix. E.g. Body region "TBI" could be classified into seven possible nature of injury categories.

Propensity Score Development

Satisfactory covariate balance was achieved on the tenth iteration of the propensity score model development. After stratification and weighting, the final propensity score model had standardised differences with an absolute value no larger than 0.05 and variance ratios within 0.8 to 1.1 (Figure 2).

Analyses Comparing Relative Mortality of Patients Transported Indirectly Compared to Directly

There was no evidence to suggest that crude mortality of patients transported indirectly to definitive care differed to that of patients transported directly (2 week: RR 1.04, 95%CI 0.68, 1.58; 30-day: RR 1.12, 95%CI 0.76, 1.66) (Table 4). For patients with complete data (n = 989), the propensity-weighted adjusted model estimated 2-week mortality at 36% lower (aRR 0.64, 95%CI 0.38,1.06) for those transported indirectly; for 30-day mortality this was 30% lower (aRR 0.70, 95%CI 0.42, 1.16) (Table 4, Supplementary Table 3). These models adjusted for age, comorbidity, mechanism of injury, primary diagnosis, ISS, Head AIS2+, Chest AIS2+, incident GCH, ICP at incident, ≥1 advanced EMS intervention for LTE, prehospital time to first hospital (log-transformed), initial vital signs at hospital: GCS, SBP, and intubation prior to definitive care.

For patients ≥55 years, the propensity-weighted adjusted model provided weak evidence indicating lower mortality for those indirectly transported (2-week aRR 0.55 95%CI 0.29,1.04; 30-day aRR 0.56 95%CI 0.30, 1.05) whereas for younger patients, point estimates suggested higher mortality for those indirectly transported although confidence intervals indicate considerable uncertainty (2-week aRR 1.20, 95%CI 0.55,2.63; 30-day aRR 1.31 95%CI 0.64, 2.69). Post-hoc analyses that explored the impact of the propensity weights and the "opportunity for indirect" inclusion criteria indicate findings are relatively robust (Supplementary Table 4).

Discussion

Significant differences were observed in the demographic, injury and clinical characteristics of study patients directly transported to definitive care compared to those indirectly transferred; this included that the median time to definitive care was considerably shorter for those transported directly (~2 hours compared to 8). Propensity-weighted adjusted models estimated reduced mortality for those transported indirectly; 36% and 30% lower respectively for 2-week and 30-day, although there was considerable uncertainty around these estimates with confidence intervals ranging from 62% less to 6% higher for 2-week mortality and from 58% less to 16% higher for 30-day mortality for those transported indirectly. For patients 55 years or older, both 2-week and 30-day mortality in indirectly transported patients was almost half that of those directly transported (aRRs 0.55 and 0.56 respectively). The opposite pattern was observed for younger patients with higher mortality observed for those transported indirectly (20% and 31% for 2-week and 30-day respectively), although confidence intervals were wide.

A higher proportion of study patients were indirectly transferred if the closest hospital was a mid-level TC, the injury occurred in a suburban area (U2), patients were children (<14 years) or Māori. In our study, of the 166 injured in suburban areas, 90% had a mid-level TC as the closest hospital and 85% were indirectly transported (in comparison, in rural areas 22%-33% were indirectly transported). The higher proportion of Māori indirectly transported are likely to be due to different population distributions across the urban-rural spectrum. [23] The higher proportion of children being indirectly transferred could be partly explained by the smaller number of specialised paediatric TCs. [28] Studies have previously found that children are more frequent among patients transferred than those directly admitted to TCs. [12, 29, 30]

Indirectly transported patients in this study were more likely to be assessed on-scene as having an immediate TTL yet were less likely to have had an ICP attend the incident and

Table 2: Clinical Characteristics of Major Trauma Patients by Directness of Transport to Definitive Care Hospital (N = 1,008)

	Direct n = 638		Indirect n = 370		χ^2 p-value
	n	col %	n	col %	
Despatch priority high (red/purple)	327	51.3	171	46.2	0.1
Intensive Care Paramedic (ICP) at incident*	494	77.8	214	58.0	<0.001
Clinical status at scene					<0.001
Immediate Threat to Life (TTL)	107	16.8	121	32.7	
Potential TTL	364	57.1	166	44.9	
No/Unlikely TTL	167	26.2	83	22.4	
Initial Glasgow Coma Scale (GCS) at scene*					0.2
Mild (13-15)	502	78.7	273	74.0	
Moderate (9-12)	52	8.2	36	9.8	
Severe (<9)	84	13.2	60	16.3	
Initial Systolic Blood Pressure (SBP) at scene*					0.9
<100	80	12.5	47	12.7	
100-119	144	22.6	82	22.2	
120-139	187	29.3	96	25.9	
≥140	216	33.9	128	34.6	
Initial respiratory rate at scene*					0.09
<12	19	3.0	7	1.9	
12-30	545	86.0	332	90.7	
>30	70	11.0	27	7.4	
Most life-threatening event (LTE) identified at scene*					0.01
Airway	18	2.8	6	1.6	
Breathing	91	14.3	39	10.6	
Circulation	36	5.7	11	3.0	
Neurological	50	7.8	46	12.5	
No LTE identified at scene	442	69.4	266	72.3	
Prehospital intervention for LTE					<0.001
At least one Advanced	262	41.1	87	23.5	
Basic only	164	25.7	94	25.4	
None	212	33.2	189	51.1	
Intubation prior to definitive care**	73	11.4	102	27.6	<0.001
Response time, mins (median, IQR)	18	(18)	15	(13)	0.002
Prehospital time to 1st hospital, mins (median, IQR)	117	(63)	73	(55)	<0.001
Total time to definitive care, mins (median, IQR)	117	(63)	474	(312)	<0.001

*Small amounts of missingness in some variables: ICP 4; GCS 1; SBP 28, Respiratory Rate 8; LTE 3.
**Intubation undertaken by EMS, plus for patients transported indirectly, procedures undertaken in the Emergency Department of first hospital.

less likely to have had any advanced prehospital intervention for LTEs. This could be because EMS clinical guidelines recommend patients be transported to the closest hospital if the patient has an LTE requiring immediate intervention that cannot be provided by personnel at the scene, the medical facility has appropriate personnel/facilities, and the patient can be transported to the staging medical facility significantly faster than the helicopter can locate at the scene. [31]

Our study, although designed to be similar to a propensity-adjusted study by Garwe, obtained different conclusions. [12] In Garwe's study, patients transported indirectly to a Level 1 TC in Oklahoma during 2006-2007 had almost three-fold (hazard ratio 2.7, 95%CI 1.3, 5.6) 2-week mortality compared to those directly transported. In comparison, in our study, 2-week mortality for those transported indirectly was 0.64 times (95%CI 0.38, 1.06) that of patients directly transported. An Israeli study that considered trauma patients (ISS≥16)

Table 3: Mortality of Major Trauma Patients by Directness of Transport to Definitive Care Hospital (N = 1,008)

	Direct n = 638		Indirect n = 370		χ^2 p-value
	n	col %	n	col %	
All ages (N)	638		370		
Died in hospital*	58	9.1	33	8.9	0.9
Time to death in hospital (from EMS call)					
2-24h*	21	3.3	5	1.4	
1 -14 days**	31	4.9	25	6.8	
15-30 days**	3	0.5	3	0.8	
>30 days	3	0.5	0	0.0	
Died following discharge ≤30 days from EMS call	2	0.3	4	1.1	
2-week mortality	53	8.3	32	8.6	0.9
30-day mortality	57	8.9	37	10.0	0.6
By age group					
<55 years (n)	410		254		
2-week mortality	24	5.9	14	5.5	0.9
30-day mortality	26	6.3	17	6.7	0.9
≥55 years (n)	228		116		
2-week mortality	29	12.7	18	15.5	0.5
30-day mortality	31	13.6	20	17.2	0.4

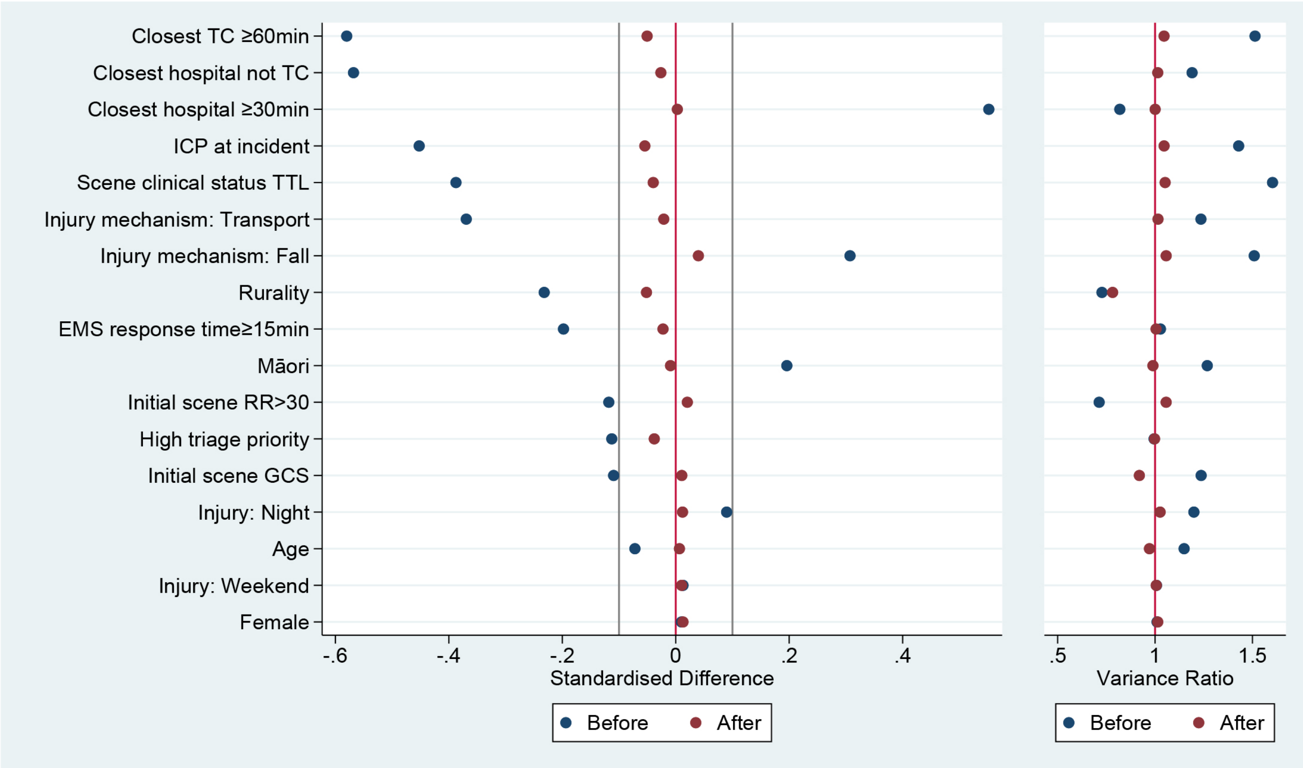
*Those that died in hospital within 2 hours of EMS call (n = 5) were considered to have been unsalvageable and were thus excluded.
**1–14 days is operationally defined as >24 hours and ≤13 midnights; similarly, for 15-30, 0-14 and 0-30 days.
***2-week mortality includes those that died within 0-14 days from EMS call; 30-day mortality includes those that died 0-30 days from EMS call.

Table 4: Multivariate Analyses: Short-term Mortality of Major Trauma Patients by Directness of Transport to Definitive Care Hospital (Indirect Compared to Direct)

	n	2-week mortality*		30-day mortality*	
		RR	95% CI	RR	95% CI
All ages					
Crude	1,008	1.041	(0.684, 1.584)	1.119	(0.755, 1.659)
Complete case					
Crude	989	1.044	(0.681, 1.600)	1.145	(0.766, 1.710)
With propensity weights	989	0.896	(0.519, 1.545)	0.928	(0.560, 1.540)
Adjusted**	989	0.638	(0.383, 1.063)	0.697	(0.421, 1.156)
By age group					
<55 years					
Crude	664	0.942	(0.496, 1.787)	1.055	(0.584, 1.907)
Complete case					
Crude	652	0.921	(0.475, 1.785)	1.043	(0.568, 1.914)
With propensity weights	652	0.910	(0.427, 1.939)	0.921	(0.459, 1.850)
Adjusted**	652	1.198	(0.546, 2.629)	1.314	(0.642, 2.689)
≥55 years					
Crude	344	1.220	(0.708, 2.104)	1.268	(0.757, 2.126)
Complete case					
Crude	337	1.225	(0.708, 2.120)	1.314	(0.778, 2.219)
With propensity weights	337	0.974	(0.470, 2.012)	1.020	(0.511, 2.035)
Adjusted**	337	0.549	(0.288, 1.044)	0.563	(0.301, 1.053)

*Prehospital deaths and 'likely unpreventable' deaths within first 2 hours of hospitalisation were excluded.
**With propensity weights and adjusted for Age, Charlson Comorbidity Index, Mechanism, Primary diagnosis, ISS, Head AIS2+ and Chest AIS2+, GCH of incident, ICP at incident, ≥1 advanced EMS intervention for LTE, Prehospital time to first hospital (log-transformed), Initial vital signs at hospital: GCS & SBP, Intubation prior to definitive care.

Figure 2: Standardised Differences and Variance Ratios Before and After Propensity Score Adjustment



from 2010-2019 reported that transfers had a greater risk of in-hospital mortality [29], whereas a Dutch study that undertook a sub-analysis of adult major trauma patients reported in-hospital mortality did not differ significantly between patients admitted directly compared to transferred to a Level 1 TC [30]. Varied geographical terrain, population density and distances to TCs may, in part, explain these differences.

We found that for those directly transported compared to indirectly, short-term mortality of older patients (≥55 years) was likely to be higher whereas for younger patients (<55 years) there was no evidence of a statistically significant survival benefit. Interestingly when comparing survival benefit following admission to a TC compared to non-TC, MacKenzie et al reported that younger patients (<55 years) had a survival benefit with no evidence of a difference in the relative risk of death for older patients [6]. Of the three studies in the previous paragraph that compared mortality between directly and indirectly transported TC patients, age-stratified analyses were only included in the Israeli study [29]. Although the direction of their findings was the opposite to ours, differential risk of in-hospital mortality was reported between the three age-groups. Following finding that older patients benefited less from direct transportation, a study that used the American National Trauma Databank surmised that older patients with comorbidities have less to gain from direct transportation as specialised treatment might not be suitable due to risks of serious complications [32].

NZ's relatively small population (5.3 million) and geographical size (268,690 km^2 – similar to Great Britain's 209,331 km^2) contributes to a trauma system with some unique features. These include: a nationally-funded no-fault system (Accident Compensation Corporation; ACC) that covers all trauma-related costs enabling accessible care for all New Zealanders; four regional networks (each with at least one tertiary trauma hospital) that ensure specialised care is available across the country; two EMS providers - one of which covers 90% of the population; and National Trauma Network leadership in developing national standards and models of care for trauma patients, working with various stakeholders including EMS, hospital and primary care experts. Also in NZ, mid-level and advanced-level trauma care hospitals are considered specialised TCs with a mid-level TC (Level II) able to provide comprehensive clinical care for major trauma patients [20]. Country-specific features, like these, reflect diverse demographics and healthcare infrastructures and contribute to considerable variability between trauma systems [33]. An analysis of eight countries across five continents outlined numerous differences in trauma care structure and regulation, patterns of injury, data collection and accessibility [33]. Challenges with accessibility for rural populations in countries like Canada and Australia, often result in limited or delayed trauma care whereas in the United States and South Africa, differences between public and private systems are related to disparities in quality of and access to care [33]. Given the variation between countries, a transferable lesson from this study is the importance of investigating age-related patterns when examining the impact of transport pathways on outcomes for major trauma patients.

The strengths of this study include its population-based nature, the inclusion of prehospital measures, and the universal nature of EMS care delivery in NZ which is not limited by insurance status. A major challenge of research on the impact of directness of transport for major trauma patients is the reliance on observational study designs; the use of propensity scores to adjust for baseline differences is one of this study's strengths. An additional strength of this study is the exclusion of those injured in locations where there was no hospital closer than the definitive care TC as these patients had no opportunity for indirect transportation. Restricting to those with an opportunity for indirect transportation provides a cohort that is more appropriate for assessing the impact of decisions regarding directness of transportation.

Limitations include that retrospective design precluded the measurement and adjustment of potential confounders such as provider experience, quality, timing, or appropriateness of care at the initial facility. The criteria used to obtain the analysis cohort, particularly the exclusions of burns patients and those died in hospital within two hours of EMS call, and the time-period the data relates to should be kept in mind when considering the generalisability of this study's findings. That said, since there have been no significant changes in practice in NZ since this data was collected, the findings are still likely to be relevant to inform NZ policy and practice relating to the acute management of major trauma in the prehospital setting. It is also important to note that definitions of TCs in NZ may not be comparable to other countries. Although our study adjusted for comorbidity, it is likely that the Charlson Comorbidity Index (derived from diagnoses recorded on hospital discharge data) underrepresents the extent of comorbidities, particularly in older patients. The small number of deaths in our dataset contributed to imprecision in the estimates and limited our ability to compare outcomes for different types of indirect transport (i.e. non-TC to mid/advanced and mid to advanced TC).

The central tenet of trauma systems is that developed trauma networks will direct patients to definitive care to reduce the time to reach surgical intervention thus improving patient outcomes [34]. Our study supports this in that direct transport resulted in a considerably shorter time to definitive care, however, evidence supporting a mortality benefit was less clear and this remains a question worthy of future research [12, 13, 34]. Future research should also investigate the robustness of these findings using different methodological approaches; this could include different inclusion and exclusion criteria, alternative ways to include propensity scores and different risk prediction models.

Conclusion

Although this study of major trauma patients from NZ found no evidence of a statistically significant difference in short-term mortality between those transported directly and indirectly, findings suggest that older patients (≥55 years) admitted to a hospital prior to arrival at their definitive care TC may have lower short-term mortality. Among patients aged <55 years, the directionality of the estimates was reversed but precision was low. These findings are hypothesis-generating and further investigation is required to clarify and understand these age-related associations and to determine the likely role comorbidity plays. Untangling this is important given increasing proportions of older trauma patients in rapidly ageing populations.

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Statement on Conflicts of Interest

None declared.

Ethics

Ethical approval was obtained from New Zealand's Health and Disability Ethics Committee (reference 18NTB142). In addition, approval to access organisational administrative data was obtained from Hone Hato St John, Wellington Free Ambulance, the National Trauma Network, the National Coronial Information System (reference NZ007) and Te Whatu Ora – Health NZ.

Data Availability

The raw data from which this study's analysis dataset was derived can be requested from Hone Hato St John, Wellington Free Ambulance, the National Trauma Network, the National Coronial Information System and Health NZ – Te Whatu Ora. A de-identified derived dataset and analysis code are available from the corresponding author upon reasonable request and with the execution of a data-access agreement with the relevant custodians.

Contributor Statement

GD was the lead author and is guarantor of this paper. Study investigators (BK, RL, GD, PR, IC, CB, BdG, BD, SA) had overall responsibility for the conception of the study and contributed to the funding application and study design. GD, BdG, LM and NC were involved in the data preparation and/or analyses. GD, BK and BD drafted the manuscript and all authors contributed to the writing and the review/editing of the manuscript. All authors approved the submitted manuscript.

AI Disclosure Statement

The authors declare that no generative AI tools were used in the preparation of this manuscript.

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Supplementary Table 1: Prehospital Interventions for Life-Threatening Events (LTE) Classified into Basic or Advanced EMS care

LTE category	Prehospital intervention	EMS Care: Basic	EMS Care: Advanced
Airway			
	Laryngeal mask airway	X	
	Oropharyngeal airway	X	
	Intubation*		X
Breathing			
	CPR	X	
	Chest decompression		X
	Oxygen	X	
Circulation			
	Tourniquet	X	
	Pelvic wrap/binding/sling/splint	X	
	Adrenaline (topical, IM, IN, NEB)	X	
	Adrenaline (infusion, bolus, IV for arrest)		X
	Atropine		X
	Sodium Chloride		X
	Calcium Chloride and Sodium Bicarbonate		X
Neurological			
	Rapid Sequence Intubation on TBI patient with GCS$\leq$10		X

**Excludes RSI on TBI patient with GCS$\leq$10.

Supplementary Table 2: Pathway and Directness of Transport to Advanced/Mid-Level Definitive Care Hospital for Major Trauma patients

	Direct		Indirect		Total	
	n	col %	n	col %	n	col %
Overall (row %)	638	63.3	370	36.7	1,008	100.0
Trauma care capabilities of definitive care hospital						
Advanced-level trauma care	527	82.6	329	88.9	856	84.9
Pathway for Indirect patients:						
TC to TC: *Advanced to Advanced*			*8*	*2.2*		
TC to TC: *Mid to Advanced level*			*255*	*68.9*		
non-TC to TC: *Low to Advanced level*			*32*	*8.6*		
non-TC to TC: *Minimal to Advanced level*			*31*	*8.4*		
non-TC to TC: *Non-trauma to Advanced level*			*3*	*0.8*		
Mid-level trauma care	111	17.4	41	11.1	152	15.1
Pathway for Indirect patients:						
non-TC to TC: *Low to Mid-level*			*9*	*2.4*		
non-TC to TC: *Minimal to Mid-level*			*18*	*4.9*		
non-TC to TC: *Non-trauma to Mid-level*			*14*	*3.8*		

Supplementary Table 3: Multivariate Analyses: Short-Term Mortality of Major Trauma Patients by Directness of Transport to Definitive Care Hospital (N = 989)

Propensity-weighted models	**2-week mortality***			**30-day mortality***		
All ages: adjusted	**RR**	**95% CI**		**RR**	**95% CI**	
Indirect	0.638	0.383	1.063	0.697	0.421	1.156
Age	1.026	1.015	1.036	1.026	1.016	1.036
Charlson Comorbidity (Quan): ≥1*	2.319	1.483	3.625	2.292	1.461	3.596
Mechanism						
Transport	(ref)			(ref)		
Fall	1.599	0.933	2.741	1.463	0.887	2.411
Other	0.665	0.337	1.314	0.632	0.335	1.195
Primary diagnosis						
Traumatic brain injury (TBI)	(ref)			(ref)		
Fracture (excl TBI)	0.332	0.163	0.675	0.295	0.152	0.572
Spinal Cord Injury	1.065	0.559	2.028	0.964	0.508	1.829
Internal organ injury (excl TBI & SCI)	0.272	0.085	0.869	0.204	0.066	0.628
Other	1.076	0.410	2.824	0.886	0.323	2.430
ISS	1.014	0.996	1.033	1.017	1.000	1.034
Head AIS≥2	0.501	0.235	1.067	0.464	0.218	0.990
Chest AIS≥2	0.450	0.268	0.757	0.523	0.327	0.835
GCH of incident						
U1	(ref)			(ref)		
U2	1.818	0.980	3.376	1.635	0.877	3.047
R1	1.217	0.668	2.217	1.174	0.660	2.091
R2	2.084	1.074	4.046	1.772	0.916	3.427
R3	1.573	0.617	4.012	1.701	0.712	4.063
ICP at incident	0.510	0.334	0.779	0.563	0.376	0.843
≥1 advanced prehospital intervention for LTE	2.180	1.403	3.387	1.810	1.154	2.839
Prehospital time to 1st hospital (mins)**	0.637	0.401	1.012	0.669	0.431	1.038
Initial hospital SBP <100	2.910	1.796	4.716	3.015	1.923	4.729
Initial hospital GCS <9	5.284	2.485	11.239	4.842	2.502	9.369
Intubation prior to definitive care	1.594	0.761	3.335	1.747	0.887	3.440

*Prehospital deaths and 'unsalvageable' deaths within first 2 hours of hospitalisation were excluded.
**Prehospital time to first hospital was log-transformed.

Supplementary Table 4: Sensitivity Analysis: Multivariate Analyses of Short-Term Mortality of Major Trauma Patients by Directness of Transport to Definitive Care Hospital (indirect Compared to Direct)

	(A) Main analysis (Table 4)		**(B) Adjusted analysis without propensity weights**		**(C) Removing "opportunity for indirect" criteria, crude and adjusted analysis without propensity weights**	
	(N = 989)		**(N = 989)**		**(N = 2,729[3])**	
	RR	**95% CI**	**RR**	**95% CI**	**RR**	**95% CI**
2-week mortality[1]						
Crude – complete case	1.044	(0.681, 1.600)	–	–	0.912	(0.656, 1.267)
With propensity weights	0.896	(0.519, 1.545)	–	–	–	–
Adjusted[2]	0.638	(0.383, 1.063)	0.568	(0.299, 1.079)	0.736	(0.493, 1.098)
30–day mortality[1]						
Crude – complete case	1.145	(0.766, 1.710)	–	–	0.941	(0.691, 1.281)
With propensity weights	0.928	(0.560, 1.540)	–	–	–	–
Adjusted[2]	0.697	(0.421, 1.156)	0.639	(0.350, 1.165)	0.750	(0.513, 1.096)

[1]Excludes prehospital deaths and 'unsalvageable' deaths within first 2 hours of hospitalisation.
[2]With propensity weights (A only) and adjusted for Age, Charlson Comorbidity Index, Mechanism, Primary diagnosis, ISS, Head AIS2+ and Chest AIS2+, GCH of incident, ICP at incident, ≥1 advanced EMS intervention for LTE, Prehospital time to first hospital (log-transformed), Initial vital signs at hospital: GCS & SBP, Intubation prior to definitive care.
[3]Of the 2,797 in Figure 1, 11 attended more than one intermediary hospital and an additional 57 had incomplete data.