Distribution of prehospital times of major trauma cases attended by emergency medical services in Aotearoa New Zealand

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ABSTRACT

AIMS: Co-ordinated trauma systems ensure timely transport to the appropriate hospital for patients following acute trauma. The Aotearoa New Zealand National Trauma Network reports median transport times to definitive care annually but omits reporting specific prehospital time intervals. This study focusses on prehospital times for major trauma patients attended by emergency medical services (EMS) in Aotearoa New Zealand.

METHODS: An analysis of routinely collected data from a retrospectively designed prospective cohort study was undertaken. Individuals of any age who suffered major trauma (Injury Severity Score [ISS] greater than 12 or died) between 2016 and 2018 and were attended by an EMS provider were included. Descriptive analyses were performed.

RESULTS: A total of 3,334 patients met the eligibility criteria, of which 105 (3.1%) died prehospital and 121 (3.6%) died within 24 hours following hospital admission. Response time was significantly faster for patients who died prehospital (median 11.5 minutes cf 14.5 minutes for those that survived to the hospital; p=0.0002). Among hospitalised patients, the median total prehospital time was 80.6 minutes (interquartile range [IQR]: 55.2–114.0). Patients who died within 24 hours following admission had significantly faster response and transport times (p=0.0005 and 0.009 respectively).

CONCLUSION: This study is the first to map out the distribution of prehospital times for major trauma patients in Aotearoa New Zealand. It establishes a crucial baseline for the timeliness of EMS care and shines a light on the significant sex and ethnic disparities among those affected by major trauma.

Injuries are one of the main causes of disability and death worldwide and remain an important public health issue.[1] Major trauma is commonly defined as any physical injury that has the potential to cause death or long-term disability.[2,3] Although an agreed internationally standardised definition of major trauma does not currently exist, it is commonly defined in terms of injury severity through anatomical scores such as the Injury Severity Score (ISS).[4] For example, an ISS of greater than 12 is considered major trauma.[2,5]

Trauma is considered a time-sensitive condition.[6] Total prehospital time (TPT) is defined as the time spent from the emergency call to arrival at hospital.[7] A TPT of 60 minutes or less is known as the “golden hour”; this concept encourages rapid transportation of trauma patients, premised on the hypothesis that trauma patients receiving definitive care within this time have improved outcomes.[8] Although this term is well-known among emergency medical services (EMS) and trauma systems, and commonly used in trauma research, evidence supporting the relevance of the golden hour for survival is limited.[8,9] For example, there is conflicting evidence for the impact of prehospital time on mortality.[10–12] Moreover, specific prehospital intervals, such as response time or scene time, may differentially impact mortality.[12,13]

In Aotearoa New Zealand, major trauma significantly contributes to morbidity and mortality; there are approximately 2,000 injury deaths and 2,500 hospitalisations for major trauma each year.[14–17] Response times, from call receipt to scene arrival, are dictated by telephone triage. The most critical categories, “purple” (suspected cardiac or respiratory arrest) and “red” (immediately life-threatening), prompt immediate response with lights and sirens. “Orange” is for serious but not immediately life-threatening incidents, dispatched at normal speed.[18] Annual reports from Hato Hone St John indicate that response time targets are generally met for the most critical incidents.[19]

EMS target measures for response times and times to definitive care are readily reportable; however, there is a sparsity of published literature describing specific prehospital time intervals for patients with major trauma in Aotearoa New Zealand. Therefore, the aim of this study was to determine the distribution of prehospital times for major trauma patients. The findings will provide data to inform the delivery of EMS care in Aotearoa New Zealand.

Methods

Eligibility criteria

This retrospectively designed prospective cohort study analysed information from individuals of any age who suffered major trauma in Aotearoa New Zealand during the period 1 December 2016 to 30 November 2018 and were attended by one of Aotearoa New Zealand's two EMS providers.[20] The New Zealand Trauma Registry (NZTR) definition of major trauma was used, which is an *"ISS greater than 12 (based on AIS 2005 Update 2008) or death following trauma that is principally due to the injuries sustained."*[21,22] Deaths due to hangings, drownings and poisonings were excluded.[21,22] Patients who self-presented to the hospital or arrived at the hospital more than 24 hours after receiving EMS care were excluded. For cases with more than one presentation to hospital due to major trauma within the study period, the most recent presentation was selected. Patients who survived to hospital were also excluded if they met three additional NZTR exclusion criteria: 1) isolated neck of femur fracture, 2) delayed admissions (more than 7 days after injury), or 3) elderly patients with pre-existing diseases that precipitate injury or death, or those who died as a result of superficial injuries. These additional criteria were not able to be applied to those who died prehospital as the data for these exclusions were not available for the prehospital deaths.

Data derivation

The primary sources of information were Aotearoa New Zealand's EMS providers' electronic and paper patient report forms (PRF) and the NZTR. Additional information from Te Tāhū Hauora – New Zealand Health Quality & Safety Commission (HQSC), and the Ministry of Health's National Minimum Dataset of hospital discharges (NMDS) and National Health Index (NHI; Aotearoa New Zealand's unique health identifier) database was used to supplement and/or validate the data obtained.[20] The National Coronial Information System (NCIS) was used to calculate ISS for cases who died prior to arrival at hospital and were therefore not captured in the NZTR.

Response times were calculated from PRF data with the time started from the point in time that the telecommunications provider transferred the 111-emergency call to EMS providers and it was picked up by the call handlers. Prehospital time components included (from Figure 1):

1. *Activation time*: the difference between the time the request for assistance phone call was picked up and the earliest time an ambulance was enroute.
2. *Travel to scene time*: the difference between the earliest time an ambulance was enroute and the earliest time an ambulance arrived on scene.
3. *Response time*: the difference between the time the request for assistance phone call was picked up and the earliest time an ambulance arrived at scene (this is the sum of activation time and travel to scene time).
4. *On-scene time*: the difference between the earliest time an ambulance arrived at the scene and the time the transporting ambulance left the scene.
5. *Transport time*: the difference between the time the transporting ambulance left the scene and the time the transporting ambulance arrived at the hospital.
6. *Total prehospital time* (TPT): the sum of all EMS time intervals (response, on-scene and transport).

Other variables of interest included age, sex, ethnicity, mechanism of injury, dominant injury type, ISS and dispatch triage priority. This study allocated a single ethnicity per individual based on a prioritisation hierarchy according to the Ministry of Health – Manatū Hauora as described in the *HISO 10001:2017 Ethnicity Data Protocols*.[23] In addition, area-level socio-economic deprivation and rurality were assigned using the geographical injury location as recorded by EMS. The New Zealand Index of Deprivation (NZDep) 2018 is an ordinal scale where 1 represents the 10% of small areas with the lowest socio-economic deprivation and 10 represents the 10% of small areas with the highest socio-economic deprivation.[24] Rurality was allocated using the binary version of the Geographic Classification for Health (GCH).[25]

Statistical analysis

A descriptive analysis was conducted. The distribution of the characteristics of major trauma cases attended by an EMS provider is presented by prehospital mortality status using frequencies and percentages, with median and interquartile range (IQR) used for skewed continuous variables.

A comparison of times between those who died prehospital and those who survived to the first hospital was restricted to activation time and travel to scene time (i.e., response time). An additional outcome of interest was evaluated for patients who survived to 24 hours following (first) hospital admission. For each group defined by this outcome, time components are presented using medians and IQRs.

The Mann–Whitney test was used to compare the distributions of prehospital times.

A descriptive analysis to identify the reasons for prolonged on-scene time in the prehospital care of major trauma patients was also conducted. A time higher than the mean on-scene time for patients in this study that survived to hospital was considered as a delay. Stata SE version 17 was used for the analysis.[26]

Ethics

Ethics approval for the study was obtained from the Health and Disability Ethics Committee (Ref 18NTB142). Research approvals were obtained from the NZTR, Hato Hone St John, Wellington Free Ambulance (WFA) and the NCIS and New Zealand Chief Coroner (Ref NZ013) to access their data for the period of interest.

Results

A total of 3,334 patients met the eligibility criteria, of which 105 (3.1%) died prehospital and 3,229 (96.8%) survived to the first hospital (Table 1).

The majority of major trauma patients attended by EMS during the period reviewed were male (69.5%; n=2,318/3,334), and 21.6% (n=717/3,334) were Māori (Aotearoa New Zealand's Indigenous population). The median age was 48 years (IQR: 27–65), with 69.3% (n=2,310/3,334) of patients aged between 15 and 64 years. Most incidents occurred in urban areas and areas of moderate socio-economic deprivation (66%, n=2,209/3,323 and 44%, n=1,456/3,304, respectively). A dispatch triage status of red or purple, indicating cardiac or respiratory arrest, immediately life-threatening or time-critical incidents, was assigned to 45.9% of patients.

The most common mechanism of injury was transport incidents (60.9%; n=2,030/3,291), followed by falls (26.1%; n=859/3,291) (Table 1). The median ISS was 17 (IQR: 14–25); 45.7% of patients had "severe" ISS scores (16–24) and 27.7% were scored as "very severe" (ISS ≥25).

Most of the patients who died prehospital were male (73.3%: n=77/105) and younger than those who survived (median age: 44 cf 48 years). Patients who died prehospital had a significantly higher ISS than those who survived to the first hospital, with 86.7% (n=91/105) of patients who died prehospital experiencing severe trauma (ISS ≥25) compared with those who survived to the first hospital (25.7%) (Table 1).

Comparison of times between those that did and did not survive to the first hospital was restricted to response time (activation time and travel to scene time), as on-scene time and transport times are systematically different for those that were attended by EMS but died prehospital (Table 2). The median response time was shorter among patients who died prehospital compared with those who survived (11.5 vs 14.5 minutes; p=0.0002). Activation time was significantly shorter for those who died prehospital (median 2.9 minutes vs 3.7 minutes; p<0.0001); on average, activation time comprised 33% of patients' response time.

One-third (33%; n=35/105) of patients who died prehospital experienced a response time between 5 to 10 minutes, compared with 25% (n=802/3,227) of patients who survived to hospital. A smaller proportion of patients who died prehospital, 32% (n=34/105), had a response time of greater than 15 minutes compared with 48% (n=1,549/3,227) of patients who survived to hospital.

Total prehospital time (TPT) could not be calculated for four hospitalised patients due to missing data. Of the remaining 3,225 hospitalised patients, analysis of the distribution of prehospital time revealed a median TPT of 80.6 minutes (IQR: 55.2–114.0). Patients who survived to 24 hours following admission had, on average, longer TPTs than those who did not (median 81.1 cf 65.6 minutes; p=0.003) (Table 3).

For hospitalised patients, the median response time (12.4 cf 14.6 minutes; p=0.0005) and transport time (17.0 cf 20.2 minutes; p=0.009) were significantly shorter for patients who died within 24 hours of hospitalisation compared with those who survived. Response time contributed, on average, 22% of the patient's TPT. Approximately one-third of patients (30.2%; n=974/3,225) had a TPT (from EMS phone pick up) within 60 minutes ("golden hour").[8]

The median on-scene time was 30.6 minutes (IQR: 19.7–49.4); this represented, on average, 42.8% of TPT. There was no evidence of a statistically significant difference between on-scene time for patients who died within 24 hours following injury (Table 3).

On-scene delays (greater than 38.7 minutes on scene time) were present in one-third of cases that survived to hospital (35.1%; n=1,171/3,334). However, the reasons for this were only documented for 368 of these cases (31.4%; n=368/1,171). Difficult patient extrication (31.0%; n=126/368), patient's condition (24.3%; n=99/368), trapped/encased patients (19.9%; n=81/368) and multiple patients involved in the event (12.0%; n=49/368) were the most common reasons for on-scene delays.

Discussion

This descriptive analysis of a cohort study of major trauma patients in Aotearoa New Zealand confirms that major trauma in Aotearoa New Zealand most commonly occurs among males and in patients aged between 15 and 64 years; the most common mechanisms of injury are motor vehicle crashes (MVCs) and falls, while penetrating injuries are uncommon. Similar results were reported in an Australian study by Harris et al.,[27] who found that more than 70% of patients experiencing major trauma were males, with 63% of cases being due to MVCs. Patients of Indigenous Māori ethnicity are over-represented in the total cohort (22%), and of those patients who died (29%), this is markedly higher than the proportion of Māori within the Aotearoa New Zealand population, at 17%.[28] This finding is consistent with previously reported data from the Aotearoa New Zealand National Trauma Network (the Network).[29] The Network indicates that Māori experience higher rates of major trauma compared with other ethnic groups across all ages, except for those aged greater than 80 years.[29]

The median response time was quicker by around 3 minutes for patients who died prehospital, with a higher proportion of patients who survived to the hospital having response times greater than 15 minutes. Patients who died prehospital in the present study had a higher ISS, with a great proportion dispatched as time-critical triage red or purple, explaining the shorter median response time obtained for this group in this study.[17] Both groups of patients who died prehospital and those who survived to hospital had a median response time similar to that reported in other similar trauma systems such as New South Wales, Australia (15 minutes)[10] and Norway (11 minutes urban, 14 minutes suburban, 21 minutes remote).[30] Additionally, neither of these recent observational studies indicated any impact of response time on patient mortality.[10,30] Future research that has sufficient numbers to explore the relationships between triage status, prehospital time and survival would be valuable. Of the 121 that died in 24 hours following hospital admission, 24% (n=29) died within the first hour and 26% (n=31) died within 1 and 6 hours. In this study, 12% of patients who survived to hospital but died within 24 hours were triaged purple (the highest), 55% red and 33% orange or lower; for those that survived to 24 hours following admission this was 2% purple, 43% red and 55% orange or lower.

For patients who survived to hospital, on-scene time (median 31 minutes) was the biggest contributor to TPT in the present study (43%). Similar results were obtained from New South Wales, Australia where a median on-scene time of 28 minutes was reported.[10] Interestingly, in a Norwegian study, the median time on-scene time (although not significant) was longer for incidents occurring in remote locations (22 minutes) than in urban or suburban locations (16 minutes).[30] The Australian study did not demonstrate any relationship between on-scene time and mortality;[10] however, the Norwegian study found that prolonged on-scene time was associated with higher odds of mortality.[30] The most common reasons for on-scene delays in the present study were difficult extrication, patient's condition and patients who were trapped/encased in MVCs. These factors are primarily derived from a drop-down list within the Aotearoa New Zealand EMS electronic patient record, and there are likely to be additional factors not captured that may contribute to increased scene time. A Canadian study that explored paramedic perspectives of why on-scene times may exceed 10 minutes identified that scene characteristics, the collaboration of allied services (police and fire), mode of transport (e.g., waiting for helicopter EMS) and the crew's skills may impact the duration of time on-scene.[31]

In our cohort, transport time to the first hospital was the second biggest contributor to TPT with a median transport time of 20 minutes. This is similar to that reported in the Norwegian (14 minutes urban, 23 minutes suburban, 50 minutes remote)[30] and Australian studies (24 minutes).[10] Interestingly, both of these studies found that longer transport times may be associated with reduced mortality, which was also in alignment with an earlier observational study from the United States of America (USA).[10,30,32]

The median TPT for patients surviving to the first hospital with EMS-attended major trauma in Aotearoa New Zealand was 81 minutes, exceeding the "golden hour"[8] by 21 minutes. Australian estimates of median TPT also exceed the "golden hour"; however, only by 12 minutes.[10] Our study found that TPT and EMS time intervals in patients who survived to hospital are longer in those patients who survived more than 24 hours compared with those who died within 24 hours following injury. It may be that in developed trauma systems, longer prehospital times are not associated with increasing mortality because the highest acuity and most unstable patients have the shortest prehospital time intervals, and the lowest acuity/more stable patients have the longest. Studies to address the confounding in injury severity and type of injury are of future interest to address this.

Strengths and limitations

A key strength of this research is that it is the first study to use national data to describe the prehospital time intervals for patients with major trauma using a standard definition of major trauma. However, the EMS time-related data were not externally validated and, therefore, potentially subject to bias. We observed cases in our database with incomplete and/or improbable times (e.g., departure time preceded arrival time). These times were verified and, where possible, corrected.

Although we do have time to death following hospital admission, we were limited in terms of possible analysis given; in this cohort, there were only 121 deaths in hospital in the 24 hours following admission. Therefore, our study focussed on 24-hour mortality for hospitalised patients. If there were higher numbers of patients, additional analysis of the shorter time periods may have identified bleeding patients who could have survived with shorter prehospital times.

Those who died prehospital were unable to be assessed for additional NZTR exclusion criteria as described in the methods, as these data are only collected in-hospital. This may have impacted the characteristics described for the prehospital deaths. However, it is notable that the median age for those who died prehospital was 44, the majority of these were in road traffic incidents and more than 85% of prehospital deaths had an ISS ≥25, so it is likely that very few, if any, of these would have met these additional exclusions had they been able to be assessed.

This study did not characterise time to definitive care, only time to the first hospital. Time to definitive care includes the time interval for patients transferred between hospitals and is routinely reported elsewhere.[14] This study was confined to characterising prehospital time intervals, and it provides a valuable baseline for EMS; however, future analysis could investigate the relationship between such intervals and mortality. This study uses data corresponding to EMS care delivered in Aotearoa New Zealand between 2016 and 2018. There is the potential for different outcomes with more recent data, and this may not reflect current practice.

Conclusion

This study provides a comprehensive overview of the demographics, injury profiles and prehospital time distribution for major trauma patients in Aotearoa New Zealand. It establishes a vital benchmark for the efficiency of EMS care and highlights significant disparities in sex and ethnicity among trauma victims. These insights are crucial for shaping future trauma care strategies and ensuring equitable treatment for all patients.

Figure 1: Emergency medical services prehospital time intervals.

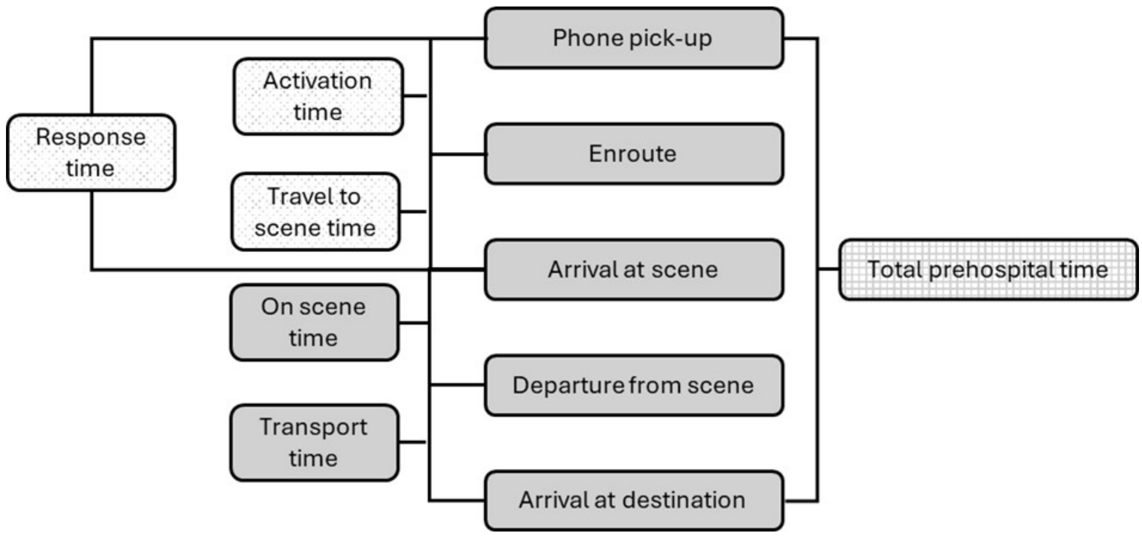

Table 1: Demographic and injury characteristics of emergency medical services-attended major trauma patients in Aotearoa New Zealand by prehospital mortality status, 2016–2018.

Characteristics*	Died prehospital	Survived to first hospital	Total	p-value**
	n=105	n=3,229	n=3,334	
	n (%)	n (%)	n (%)	
Sex				
Female	28 (26.7)	988 (30.6)	1,016 (30.5)	0.4
Male	77 (73.3)	2,241 (69.4)	2,318 (69.5)	
Median age in years (IQR)	44 (25–60)	48 (27–65)	48 (27–65)	<0.001
Ethnicity (prioritised)				
Māori	30 (30.6)	687 (21.3)	717 (21.6)	0.03
Non-Māori	68 (69.4)	2,542 (78.7)	2,610 (78.4)	
Geographic Classification for Health of incident				
Urban	66 (62.9)	2,143 (66.6)	2,209 (66.5)	0.4
Rural	39 (37.1)	1,075 (33.4)	1,114 (33.5)	
NZDep2018 of incident				
1–3 (low deprivation)	24 (22.9)	813 (25.4)	837 (25.3)	0.7
4–7	50 (47.6)	1,406 (44.0)	1,456 (44.1)	
8–10 (high deprivation)	31 (29.5)	980 (30.6)	1,011 (30.6)	

Table 1 (continued): Demographic and injury characteristics of emergency medical services-attended major trauma patients in Aotearoa New Zealand by prehospital mortality status, 2016–2018.

Triage priority				
Purple/red (high)	56 (53.3)	1,472 (45.7)	1,528 (45.9)	0.1
Other	49 (46.7)	1,751 (54.3)	1,800 (54.1)	
Mechanism of injury				
Transport	71 (76.3)	1,959 (61.3)	2,030 (61.7)	0.001
Fall	8 (8.6)	851 (26.6)	859 (26.1)	
Other specified	14 (15.1)	388 (12.1)	402 (12.2)	
Injury intent				
Intentional	9 (8.6)	281 (8.7)	290 (8.7)	1.0
Unintentional	96 (91.4)	2,933 (91.3)	3,029 (91.3)	
Median Injury Severity Score (IQR)	57 (34–75)	17 (14–25)	17 (14–25)	<0.001
Injury Severity Score (ISS) groups				
Minor/moderate (ISS 1–15)	5 (4.8)	881 (27.3)	886 (26.6)	<0.001
Severe (ISS 16–24)	9 (8.6)	1,513 (46.9)	1,522 (45.7)	
Very severe (ISS ≥25)	91 (86.7)	830 (25.7)	921 (27.7)	

*Small amounts of missingness were present for ethnicity (n=7), rurality (n=11), deprivation (n=30), triage priority (n=6), mechanism (n=43), injury intent (n=15) and ISS (n=5). The geographical injury location was used to assign the New Zealand Index of Deprivation (NZDep) 2018 (1=lowest deprivation, 10=highest) and rurality (binary version of the Geographic Classification for Health [GCH]).
**χ^2 test was used for categorical variables; Mann–Whitney U-test for continuous variables. Those with responses "not recorded" or "unknown" were not included in the χ^2 test.
IQR = interquartile range; NZDep = New Zealand Index of Deprivation; ISS = Injury Severity Score.

Table 2: Distribution of response time (activation time and travel to scene time) by prehospital mortality for emergency medical services-attended major trauma patients in Aotearoa New Zealand, 2016–2018.

Time components (minutes)	Died prehospital (n=105) Median (IQR)	Survived to first hospital (n=3,227*) Median (IQR)	Total (n=3,332*) Median (IQR)	Mann–Whitney p-values	Contribution % (95% CI)
Response time	11.5 (8.0–17.1)	14.5 (9.4–23.8)	14.4 (9.4–23.6)	0.0002	
Activation time	2.9 (1.7–4.4)	3.7 (2.6–5.7)	3.7 (2.6–5.7)	<0.0001	32.6 (31.9, 33.3)
Travel to scene time	8.0 (5.4–13.8)	9.8 (5.7–16.8)	9.8 (5.6–16.7)	0.06	67.4 (66.7,68.1)

*Those for whom response time could not be calculated were removed from analysis (n=2).
IQR = interquartile range; CI = confidence interval.

Table 3: Distribution of total prehospital time and prehospital time components by 24-hour mortality after hospitalisation for emergency medical services-attended major trauma patients in Aotearoa New Zealand that survived to hospital, 2016–2018.

Time components (minutes)	Died within 24 hours following injury (n=121) Median (IQR)	Survived to 24 hours following injury (n=3,104*) Median (IQR)	Total (n=3,225*) Median (IQR)	Mann–Whitney p-values	Contribution % (95% CI)
Total prehospital time	65.6 (46.1–108.7)	81.1 (55.6–114.4)	80.6 (55.2–114.0)	0.003	
Response time	12.4 (8.4–17.3)	14.6 (9.5–23.9)	14.5 (9.4–23.8)	0.0005	22.0 (21.6, 22.4)
On-scene time	28.4 (17.7–47.5)	30.7 (19.8–49.5)	30.6 (19.7–49.4)	0.2	42.8 (42.2, 43.5)
Transport time	17.0 (7.8–29.9)	20.2 (11.4–33.5)	20.1 (11.3–33.4)	0.009	28.2 (27.7, 28.7)

*Those for whom response time or on-scene time could not be calculated were removed from analysis (n=4).
IQR = interquartile range; CI = confidence interval.

COMPETING INTERESTS
GD acknowledges a Health Research Council payment made to their institution. GD is on the Data Governance Group for the New Zealand Major Trauma Registry.
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BK is an employee of The University of Auckland, and this work was undertaken as part of her employment.

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