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Meta analysis

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Trauma outcomes at higher-level trauma centres compared with lower-level trauma centres: a systematic review and meta-analysis

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ABSTRACT

The introduction of trauma systems has helped reduce mortality in severely injured patients. This fall in mortality, however, appears to be concentrated in higher-level trauma centres (TCs) in comparison to lower-level TCs, but the evidence is inconsistent. Therefore, we undertook a systematic review with the aim of comparing outcomes in lower-level TCs (i.e. level III and IV trauma centres) with higher-level TCs (i.e. level I and II centres). This systematic review was performed in accordance with the guidelines defined in the preferred reporting items for systematic reviews and meta-analyses statement (PRISMA). The review was registered on PROSPERO (CRD42019111933). Mortality data were combined using the Mantel-Haenszel random-effects method for meta-analysis, using Review Manager (RevMan v5.3.5). We found 28 eligible articles from an initial total of 10,816 identified abstracts. Our meta-analysis revealed no evidence of a difference in mortality risk in severely injured patients between lower-level and higher-level TCs (RR 1.55; 95% CI 0.97 to 2.50; p=0.07), but there was considerable heterogeneity (I2=92%) in the dataset. The risk of death in lower-level TCs in patients with neurological trauma, however, was statistically lower than in higher-level TCs (RR 0.80; 95% CI 0.73 to 0.86; I2=78%; p<00001). There was a higher risk of death in patients with neurological trauma managed at higher-level TCs and this is likely to be due to the higher severity of injury (intracranial and extracranial) sustained by patients at higher-level TCs. However, the high level of heterogeneity in the risk estimates of evaluated studies reduces the certainty of our interpretations.

Keywords: Trauma centers, Wounds and injuries, Epidemiology, Mortality, Complications, Systematic review

INTRODUCTION

Trauma is an important cause of death worldwide, accounting for 9% of the world's deaths, and is predicted to become the seventh leading cause of death by 2030.[1] Most trauma-related deaths are a result of road injury (29%), followed by self-harm (18%) and falls (12%).[2] In the United Kingdom (UK), despite a 39% decrease in deaths from road-traffic accidents between 2007-2017, it remains an important cause of death and disability.[3,4] As such, optimal management of the severely injured patient should be a priority in the UK and worldwide.

Evidence from North America indicates that regionalisation of trauma care - treating patients with major trauma at specialist level I trauma centres (TC), as part of a trauma system - leads to a considerable reduction in mortality.[5-7]

Historically, trauma care in the UK has been more fragmented, with poorer outcomes compared to other developed nations with existing trauma systems.[8,9] For instance, patients who sustained severe head injuries were routinely admitted to non-neurosurgical centres, and subsequently suffered from higher mortality rates.[10,11] In

2007, the national confidential enquiry into patient outcome and death (NCEPOD) reported that substandard care was provided to almost 60% of all trauma patients.[12]

Following these adverse findings, the UK's first trauma system was implemented in London in 2010, and subsequently nationwide in 2012. The UK's trauma system consists of a network of major trauma centres (MTCs) - similar to level I and II TCs in North America - linked with a number of trauma units (level III and IV TCs).[13]

Evidence suggests that the introduction of the trauma system in the UK helped reduce mortality in severely injured patients.[13,14] However, this fall in mortality appears to be concentrated in MTCs, and not the lower level centres.[13] Similarly, evidence from North America revealed lower survival rates in level III trauma centres compared to level I centres, despite level III centres receiving less seriously injured patients.[15,16]

Even among higher-level TCs in the United States of America (USA), level I centres have demonstrated lower mortality rates compared to level II centres.[17] In contrast, two systematic reviews did not show any survival benefit in direct admission to a higher-level TC compared to admission to a lower-level TC and subsequent transfer to a higher-level TC, although the evidence base was considerably heterogeneous.[18,19]

The potential discrepancy in outcomes between higher and lower-level TCs is clearly of concern, but the extent of the differences in outcomes and the reasons behind them have not been fully explored in the literature, which has not been helped by the heterogeneity of existing data sets.[18,19]

Identification of factors affecting potentially worse outcomes of injured patients at lower-level TCs would help target deficiencies in care and improve the functioning of the entire trauma system. It would be desirable to establish whether an observed outcome gap between centres could be due to best practices at higher-level TCs or inadequate care at lower-level TCs, or both.

Our primary aim, therefore, was to perform a systematic review to compare outcomes in lower-level TCs (i.e., level III and IV trauma centres) compared with higher-level TCs (i.e., level I and II centres). Our secondary aim was to describe factors that could explain potential discrepancies in outcomes between the different levels of trauma care.

METHODS

This systematic review was performed in accordance with the guidelines defined in the preferred reporting items for systematic reviews and meta-analyses statement (PRISMA).

The review was registered on PROSPERO (CRD42019111933).

Information sources and search details

MEDLINE and EMBASE databases were both searched from inception to June 2019.

Search terms based on the population ("trauma" or "trauma centers" [mesh] or "trauma system"), intervention ("district general hospital" or "trauma unit" or "level 3" or "level 4" or "level III" or "level IV"), comparator ("level I" or "level II" or "major trauma cent*"), and outcomes ("survival" or "mortality" or "disability" or "morbidity" or "complication*") (PICO) framework were used to identify eligible studies.

Reference lists of eligible studies were searched to identify relevant studies missed through the above search strategy.

Study eligibility criteria

Inclusion criteria were as follows: full text articles, in English; and studies comparing outcomes in level I-II (higher-level TCs) and level III-IV TCs (lower-level TCs).

Exclusion criteria were as follows: conference abstracts and posters; case reports; and (3) case series'.

Study selection and data collection

Two review authors (N.J. and I.L.) performed the initial search and identified relevant studies using the pre-specified search strategy and inclusion/exclusion criteria.

Abstracts of interest underwent initial evaluation for relevance; unsuitable articles were excluded from further analyses. The selected articles were then read in full and evaluated by the authors independently (N.J, S.A, and I.L.).

Data extraction

The authors independently extracted relevant items of interest from the included articles. For the primary outcome, data items extracted include type of study, study location, patient demographics (age/gender), mechanisms of injury, injury severity (as defined by either the injury severity score (ISS), abbreviated injury scale (AIS), revised trauma score (RTS) or new injury severity score (NISS), organ systems affected, transfer status (i.e. direct admission or transfer from other hospitals), mortality or survival rates, other reported outcomes, and any complications of care (as reported in the study).

Other outcomes of interest include treatment options offered, time taken to offer relevant treatments, hospital and intensive care length of stay, discharge destination, and any others of relevance reported by the included studies. Relevant complications included those related to the injuries, hospital and intensive care stay, and those related to the treatments used.

Meta-analysis

Mortality was an outcome measure that was suitable for meta-analysis. To allow for comparison between higher-level and lower-level TCs, event rates were combined between level I and level II TCs (for higher-level TCs) and between level III and level IV TCs (for lower-level TCs).

Mortality data were combined using the Mantel-Haenszel random-effects method and effects were expressed as a relative risk ratio with 95% confidence intervals (CI). Statistical significance was set at the 95% level ($p<0.05$). Heterogeneity was assessed using I^2 and interpreted as follows: 0% to 40% might not be important, 30% to 60%: may represent moderate heterogeneity, 50% to 90%: may represent substantial heterogeneity, and 75% to 100%: considerable heterogeneity.

When heterogeneity was present in an analysis, we explored potential explanations, such as the removal of extreme study effects, and differences in patients, severity of injury, country of origin, and study design, where applicable. All analyses were performed using Review Manager (RevMan v5.3.5; The Cochrane Collaboration, 2014).

RESULTS

Study selection

An initial total of 10,816 abstracts were identified. Of these, 10,707 records were excluded. Hundred and nine full-text articles were assessed and 81 of these excluded. Finally, a total of 28 articles were included for analysis. The flow diagram in Figure 1 illustrates the study selection steps.

Characteristics of studies

Table 1 summarises all the included studies.

Of the 28 included studies, the majority were based in North America, with 20 reports from the USA and 3 from Canada.[7,15,20-49] Three studies were based in Europe- 2 from the UK and 1 from Portugal- and the remaining 2 studies were from Australia.[41-45]

The included studies were categorised as follows: studies in paediatric settings; studies in severely injured patients; studies on neurological trauma; studies evaluating trauma systems; studies on organ and regional trauma; studies on falls and minor injuries; and studies on specific population groups.

Summary of results: mortality

Table 1 summarises the studies reporting mortality data. All but three of the studies reported mortality statistics. Of these 25 studies, only 11 were eligible for inclusion into a meta-analysis. These studies were subcategorised into the following subgroups: mortality in paediatrics; mortality in severely injured patients; mortality in neurological trauma; and mortality across trauma systems. Figure 2 is a forest plot illustrating the risk ratios for mortality across the defined subcategories.

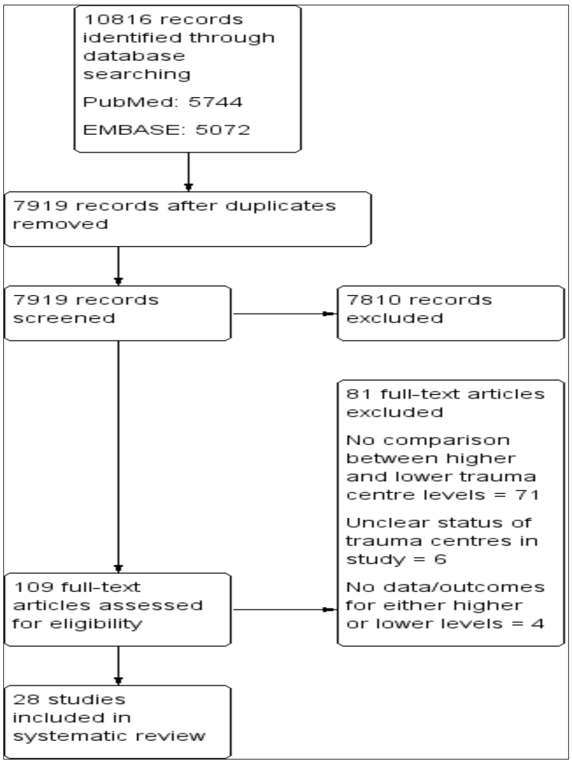

Figure 1: PRISMA flowchart.

Table 1: Mortality study data.

Study or subgroup	Lower-level TC		Higher-level TC			Risk ratio
	Events	Total	Events	Total	Weight (%)	M-H, random, 95% CI
Paediatric						
Distelhorst 2017	35	1817	21	675	47.0	0.62 (0.36, 1.06)
Amini 2011	111	3162	164	7891	53.0	1.69 (1.33, 2.14)
Subtotal (95% CI)		4979		8566	100.0	1.05 (0.39, 2.81)
Total events:	146		185			
Heterogeneity: $Tau^2=0.46$; $Chi^2=11.34$, df=1 (p=0.0008); $I^2=91\%$						
Test for overall effect: Z=0.10 (p=0.92)						
Severely injured patients						

Continued.

Study or subgroup	Lower-level TC		Higher-level TC			Risk ratio
	Events	Total	Events	Total	Weight (%)	M-H, random, 95% CI
Curtis 2011	48	279	232	1707	32.3	1.27 (0.95, 1.68)
Demetriades 2006	39	210	10652	71054	32.4	1.24 (0.93, 1.65)
Dufresne 2017	178	239	159	493	35.3	2.31 (1.99, 2.68)
Subtotal (95% CI)		728		73254	100.0	1.55 (0.97, 2.50)
Total events:	265		11043			
Heterogeneity: Tau²=0.16; Chi²=24.72, df =2 (p<0.00001); I²=92%						
Test for overall effect: Z=1.81 (p=0.07)						
Neurological trauma						
Barmparas 2015	1703	24049	1666	19588	44.5	0.83 (0.78, 0.89)
Fakhry 2017	3336	43294	11271	112208	55.5	0.77 (0.74, 0.80)
Subtotal (95% CI)		67343		131796	100.0	0.80 (0.73, 0.86)
Total events:	5039		12937			
Heterogeneity: Tau²=0.00; Chi²=4.63, df=1 (P=0.03); I²=78%						
Test for overall effect: Z=5.62 (p<0.00001)						
Trauma system overview						
Helling 2007	33	2201	821	21176	23.4	0.39 (0.27, 0.55)
Ahmed 2017	19	25	1202	1386	25.1	0.88 (0.70, 1.09)
Garwe 2010	285	3560	132	2669	25.3	1.62 (1.33, 1.98)
Egol 2011	750	24121	27787	577267	26.2	0.65 (0.60, 0.69)
Subtotal (95% CI)		29907		602498	100.0	0.78 (0.48, 1.28)
Total events:	1087		29942			
Heterogeneity: Tau²=0.24; Chi²=88.19, df=3 (p<0.00001); I²=97%						
Test for overall effect: Z=0.98 (p=0.33)						

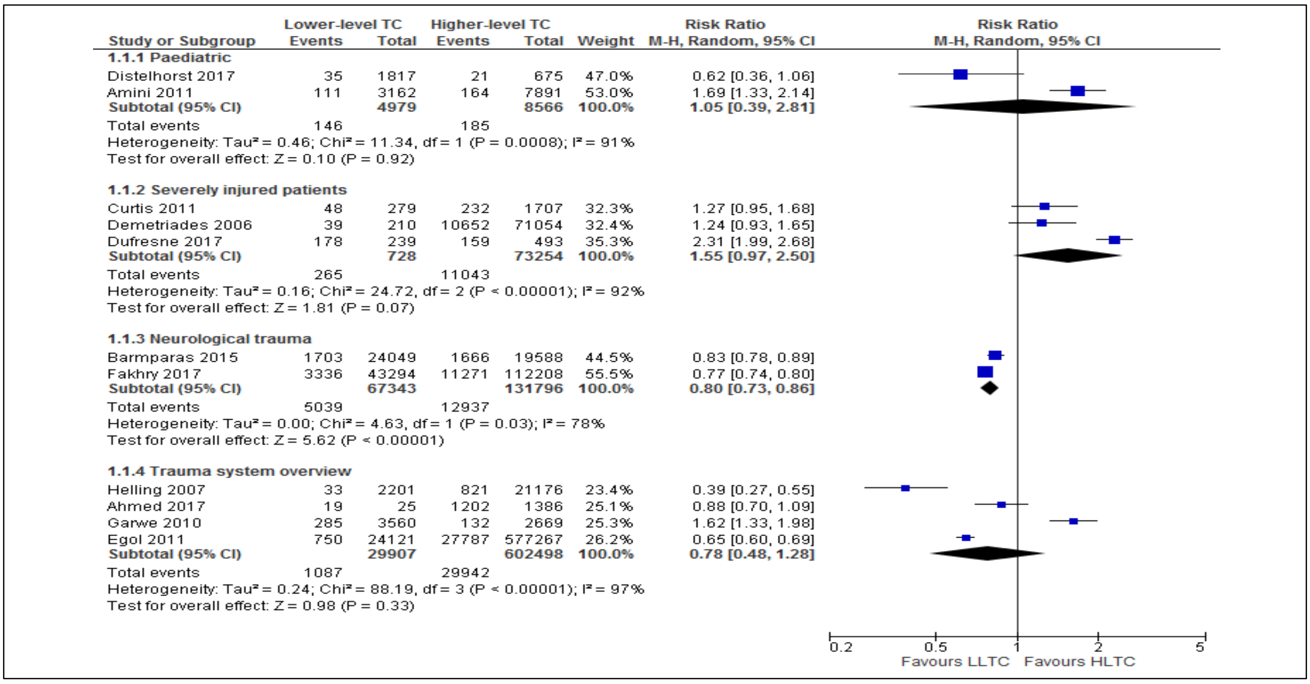

Figure 2: Forest plot illustrating risk of trauma-related mortality by subgroup.

Note: LLTC= lower-level trauma centre; HLTC= higher-level trauma centre.

Paediatrics

Two studies reported mortality data on paediatric cases and were included in the meta-analysis.[26,40] One other study reported survival but was unsuitable for inclusion.[41]

There was no evidence of a difference in the risk of death in paediatric cases at lower-level TCs compared to higher-level TCs (RR 1.05; 95% CI 0.39 to 2.81; p=0.92). However, there was considerable heterogeneity in the analysis (I^2=91%) due to the two included studies which appeared to show contradictory findings. Several reasons can explain the heterogeneity in this analysis. While both studies evaluated outcomes in paediatric cases, Distelhorst et al's study was primarily based on injured pregnant women and the outcomes of neonates after maternal trauma whereas Amini et al's study focused on injured children themselves.[26,40] Although the paediatric deaths in the Distelhorst et al study may not have been directly from trauma, the fatalities are likely to be influenced by maternal trauma and, as such, trauma was an indirect cause of death in these cases and, hence, the two studies were thought to be comparable.[26] Moreover, the majority of patients were treated in lower-level TCs in the Distelhorst et al study and vice versa in the Amini et al study.[26,40] The injury severity was also lower in the Distelhorst et al study, compared to the Amini et al study.[26,40] These factors can help explain the reduced risk of paediatric deaths seen at lower-level TCs (albeit non-significant). In the Amini et al study, lower-level TCs had a significantly higher risk of death for injured children despite treating a smaller proportion of patients, who were also less severely injured.[40]

Studies not included in meta-analysis

Vassallo et al reported on the 30-day survival of paediatric patients (age<18) who suffered a traumatic cardiac arrest in the UK.[41] The overall 30-day survival was 5.4%. Most of these survivors were treated at paediatric MTCs (85.7%) whereas none of the children admitted to a trauma unit survived.

Severely injured patients

Three studies were included in the meta-analysis.[7,15,45] A further two studies on severely injured patients did not report suitable data for inclusion.[20,44]

The meta-analysis did not reveal any evidence of a difference in mortality risk in severely injured patients between lower-level and higher-level TCs (RR 1.55; 95% CI 0.97 to 2.50; p=0.07) but the studies demonstrated considerable heterogeneity (I^2=92%), primarily due to the results from Dufresne et al.[15] In contrast to the two other studies in the analysis.[7,45] Dufresne et al reported a statistically significant higher risk of death at lower-level TCs compared to higher-level TCs.[15] Removal of the Dufresne et al study from the meta-analysis reduced the heterogeneity to 0% and revealed a 25% higher risk of death in lower-level TCs for severely injured patients compared to higher-level TCs (RR 1.25; 95% CI 1.02 to 1.53; p=0.03).[15]

Several reasons may explain this discrepancy. Firstly, Dufresne et al is a much smaller study (n=732) compared to the other two studies, especially Demetriades et al (n=130,154), and it focused on a subset of severely injured patients (haemorrhagic shock) who are likely to be at a higher risk of death regardless.[7,15] Surprisingly, lower-level TCs in the Dufresne et al study received a higher proportion of severely hypotensive patients (systolic blood pressure <50 mmHg) than higher-level TCs.[15] Treating a relatively higher proportion of severely hypotensive patients at lower-level TCs, which are unlikely to be equipped to deal with such trauma, may explain the much higher risk of death at lower-level TCs seen in this study.[15]

Studies not included in meta-analysis

Polites et al compared severely injured (ISS>16) patients treated at lower-level TCs compared to higher-level TCs in the United States.[20] Overall mortality was significantly higher in lower-level TCs than in higher-level TCs (16.9% vs 15.4%, respectively).

Curtis et al examined the outcomes of severely injured patients (ISS>15) in New South Wales, Australia.[44] Overall mortality was 13.6%. Adjusted odds ratio of death at level III TCs compared to level I TCs was 1.34 (95% CI 1.10 to 1.63).

Neurological trauma

Two studies reported mortality for patients with neurological trauma and both were included in the meta-analysis.[23-25]

The risk of death in lower-level TCs in patients with neurological trauma was significantly lower than in higher-level TCs (RR 0.80; 95% CI 0.73 to 0.86; p<0.00001). Heterogeneity was moderately high (I^2=78%).

Although both studies reported similar results, there were key differences between the two. Barmparas et al's study focused on spinal trauma in the elderly – aged >65 – which included spinal fractures and spinal cord injuries.[25] Fakhry et al's study, on the other hand, focused on patients with severe head injuries who presented to emergency departments in higher-level and lower-level TCs and the likelihood of being admitted to hospital at each TC level.[23] The majority of patients in the Barmparas et al study did not have severe injuries whereas the Fakhry et al study focused on severe head injuries, although the severity of extra-cranial injuries was not reported in this study.[23,25] The elderly cohort in Barmparas et al's study was likely to have a higher risk of death due to their age while the different location of injuries sustained in Barmparas et al's study compared to Fakhry et al's study may have influenced the differences between the two as well.[23,25]

Trauma system overviews

Ten studies reported on various trauma systems however only 4 studies provided sufficient data for inclusion in our meta-analysis.[22,34,35,37] Our meta-analysis revealed no evidence of a difference in the risk of death in lower-level TCs compared to higher-level TCs (RR 0.78; 95% CI 0.48 to 1.28; p=.33), with evidence of considerable heterogeneity (I^2=97%). The removal of no one study reduced heterogeneity.

Helling compared outcomes between levels I-III TCs in a regional trauma system over a one-year period while Egol et al compared mortality in trauma systems using a national database over a four-year period.[34,37]

Both studies reported a lower risk of death in lower-level TCs and showed some key similarities, such as a higher proportion of patients treated at higher-level TCs, including more severely injured patients, which increases the risk of death at these TCs. Although Garwe et al reported similar statistics with respect to the level of severity at higher-level, the overall risk of death was reported as higher in lower-level TCs.[35] The mean ISS in the Garwe et al study was also higher across all levels of the trauma system in comparison to Egol et al's study, which reflects the increased severity of disease at lower-level TCs.[34,35]

Data from Ahmed et al's study did not show any significant difference in the risk of death at hospital discharge for injured patients who underwent resuscitation for traumatic cardiac arrest at either higher-level or lower-level TCs.[22] However, the proportion of patients – from the overall sample - who were treated at lower-level TCs was much smaller (1.0%) than at higher-level TCs (52.5%).

Studies not included in meta-analysis

Four studies reported higher rates of death in higher-level TCs compared to lower-level TCs.[28,30,32,39]

Jarman et al aimed to analyse the differences in trauma-related mortality between urban and rural areas in the United States.[28] With level IV TCs as reference, odds of death were highest at level III TCs (2.34; 95% CI 2.23 to 2.45), followed by level II (1.84; 95% CI 1.74 to 1.95) and level I TCs (1.34; 95% CI 1.24 to 1.45). Carr et al assessed the volume and severity of patients treated at a level I TC in Pennsylvania, United States when lower-level TCs open and close over a 10-year period.[30]

During the study period, mortality rates at the level I TC ranged from 3.7%-5.7% and level III TCs ranged from 0.5%-2.3%. Gage et al investigated compliance with triage guidelines for trauma in the state of Washington, United States.[32] Mortality rate for patients directly admitted to level I TCs was 6.9%, which was almost four times as high as lower-level TCs (1.8%) or for those transferred from lower-level to level I TCs (1.8%).

One study, which evaluated the implementation of a trauma system in the Canadian province of Alberta, reported a higher risk of death for severe head injury patients in lower-level TCs.[39] Adjusted hazard ratios for mortality in severe head injury (AIS 4-9) at level III TCs was 1.25 (95% CI 1.23 to 1.28) compared to level I TCs.

The two remaining studies reported mortality statistics but it was unclear whether there was any increased risk of death in either higher-level or lower-level TCs.[21,43]

Organ injuries

Four studies on specific organ-related or regional injuries were included.[27,29,36,42] None of these were eligible for inclusion into the meta-analysis.

Hotaling et al reported on the outcomes in renal trauma at different trauma centre levels using registry data from the NTDB between the years 2002-2007.[36] Mortality was highest in level I TCs (11.4%) followed by level II TCs (10.8%) and lower-level TCs (7.5%). Metcalfe et al compared the outcomes of hip fracture patients aged>60 treated at MTCs and non-MTCs in the United Kingdom.[42] In-hospital mortality was higher in non-MTCs compared to MTCs (8.8% versus 8.1%, respectively) however the odds of in-hospital mortality at MTCs was no different to non-MTCs (OR 0.95; 0.82-1.11).

The remaining two studies did not report any difference in mortality between the two TC levels.[27,29]

Falls and minor injuries

Three studies were included in this category; two reported on falls-related injuries and one was on minor injuries.[24,33,38] None of the studies were eligible for inclusion into the meta-analysis.

One study reported higher mortality rates at higher-level TCs; the other study by Cook et al also reported similar results but the odds of death in this study was highest in lower-level TCs.[24,33] Roubik et al compared mortality by trauma centre level for adults who sustained injuries from ground-level falls using NTDB data.[24] Observed mortality rates were highest for American College of Surgeons (ACS)-verified higher-level TCs (4.45; 95% CI 4.40 to 4.51) followed by state-verified higher-level TCs (4.31; 95% CI 4.22 to 4.39), state-verified lower-level TCs (3.11; 95% CI 2.96 to 3.28), and ACS-verified lower-level TCs (2.54; 95% CI 2.41 to 2.68). Cook et al assessed the mortality rates of patients injured in ground-level falls in Texas, United States, and found that the mean adjusted OR for mortality was highest in lower-level TCs (1.22; 95% CI 0.90 to 1.66), followed by level II TCs (1.17; 95% CI 0.90 to 1.51), and level I TCs (0.71; 95% CI 0.56 to 0.91).[33]

Other patient groups

Two studies were included in this subgroup, but because only one study was available for each subgroup neither were included in our meta-analysis.

Distelhorst et al reported on maternal outcomes as well as neonatal outcomes.[26] Maternal death rate in higher-level TCs was higher (0.74%) compared to lower-level TCs (0.55%). Among patients with ISS>9, death rate was also higher in higher-level TCs compared to lower-level TCs (2.3% versus 0.3%), respectively. Bukur et al examined the effect of trauma centre level on mortality for injured patients with cirrhosis using NTDB data.[31] The adjusted OR of mortality in level I TCs compared to lower-level TCs was 0.64 (95% CI 0.48 to 0.85) while admission to level I TCs was a protective factor against mortality in multi-logistic regression analysis (OR=0.67; 95% CI 0.52 to 0.87).

Summary of results: trauma outcomes and complications

Table 2 summarises the studies which report trauma outcomes and complications.

Paediatrics

Of the three included studies, only two reported relevant outcomes or complications.[26,41]

Distelhorst et al reported neonatal outcomes and complications after maternal trauma in all injured patients as well as those with ISS≥9.[26] Neonates born to injured pregnant women admitted to higher-level TCs were more likely to suffer a number of complications in comparison to lower-level TCs, including premature birth, low birth weight, and fetal distress.

The odds of a neonate being born with low birth weight in mothers with ISS≥9 in higher-level TCs was 2.52 (95% CI 1.12 to 5.64). Vassallo et al reported a good functional outcome (Glasgow outcome score) in 2 (28.6%) of the cases who had survived traumatic cardiac arrest, at 30-days follow-up.[41] Another 2 survivors (28.6%) were moderately disabled and 1 survivor (14.3%) was severely disabled.

Severely injured patients

Of the five included studies, four reported relevant outcomes and/or complications.[15,20,44,45]

Dufresne et al showed a much longer mean length of stay in level I (25.5 days) and level II TCs (19.7 days) compared to level III (12.1 days) and level IV (5.95 days) TCs.[15] The overall rate of complications was also higher in level I (61.4%) and level II TCs (53.4%) compared to either level III (44.9%) or level IV TCs (28.0%). Polites et al reported a statistically significant, longer median length of stay in patients triaged appropriately to higher-level TCs (6 days) compared to those who were treated at lower-level TCs (5 days).[20]

The overall rate of complications was higher in higher-level TC (47.9%) compared to lower-level TCs (33.9%). Curtis et al reported that there was no significant difference in length of stay between the different trauma centre levels.[44] Curtis et al reported a longer median length of stay at level I (11 days) and level II TCs (16 days) compared to level III TCs (8 days).[45] However, median length of stay in ICU was longer in level III TCs (6 days) compared to level I TCs (4 days). Adjusted OR for discharge within 24 hours at level III TCs compared to level I TCs was 2.29 (95% CI 1.1 to 4.7).

Neurological trauma

Both studies in this subgroup reported relevant outcomes and/or complications.[23,25] Fakhry et al showed that a much higher proportion of patients with severe head injuries were discharged alive from lower-level TC EDs (23.7%) compared to higher-level TC EDs (9.0%).[23] Barmparas et al reported a similar rate of discharge home, with or without care, for all patients with spinal injuries, as well as a subgroup of those with cervical spine injuries, in both higher-level and lower-level TCs.[25] However, lower-level TCs had a higher proportion of spinal cord injury patients who were discharged home (15.9%) compared to higher-level TCs (12.6%). A higher proportion of patients underwent spinal surgery within 48 hours at higher-level TCs (5.7%) compared to lower-level TCs (4.0%).

Trauma system overviews

Among the 10 studies, only two reported relevant outcomes or complications.[32,39]

Gage et al reported that patients were more likely to be discharged home from level I TCs compared to lower-level TCs (70% versus 46.3%, respectively), and also more likely to be discharged to a rehabilitation facility from level I TCs (6.5% versus 3.0%, respectively).[32] However, a higher proportion of lower-level TC patients were discharged to a nursing facility compared to level I TCs (28.9% versus 11.1%, respectively). Mckee et al reported an overall mean length of stay of 13.6 days, which reduced by 1 day (1.02-1.11; p=0.02) after implementation of the trauma system.[39]

Organ injuries

Of the four included studies, all reported relevant outcomes and/or complications.[27,29,36,42]

Kane et al showed that the odds of having surgical stabilisation for rib fractures – compared to level I TCs - was lower at both level II (OR=0.67; 95% CI 0.65 to 0.69) and level III TCs (OR=0.24; 95% CI 0.22 to 0.26).[27]

Hotaling et al reported a longer mean length of stay in level I TCs compared to lower-level TCs (12.2 days versus 9.8 days, respectively).[36] Treatment options also differed between the two groups. Twice as many patients underwent nephrectomies at higher-level TCs compared to lower-level TCs (8% versus 4%, respectively). Similarly, 55% of patients in level I TCs and 48% in level II TCs were treated with angioembolisation but only 20% received this treatment in lower-level TCs. A higher proportion of patients were also discharged home from level I (64%) and level II TCs (67%) compared to lower-level TCs (59%).

Nelson-Williams et al did not find a significant difference in the odds of being discharged home from higher-level TCs compared to lower-level TCs (OR 0.98; 95% CI 0.85 to 1.12).[29] Metcalfe et al reported that the median length of stay was the same between MTCs and non-MTCs (15 days).[42] Median time to operation for hip fractures was lower in MTCs compared to non-MTCs (23.3 hours versus 24.2 hours, respectively) while re-operation rates were also lower in MTCs (1.1% versus 1.2%, respectively). A smaller proportion of patients were discharged home from MTCs (63.2%) compared to non-MTCs (64.4%).

Fall and minor injuries

Three studies were included in this category and all three reported relevant outcomes or complications.[24,33,38]

Roubik et al reported an overall median ICU length of stay of 3 days and a hospital median length of stay of 5 days.[24] Admission to ICU was more likely in higher-level TCs – both ACS-verified and state-verified – compared to lower-level TCs. Similar relationships were noted for other complications reported by the study, e.g. pneumonia, acute kidney injury, acute respiratory distress syndrome, and severe sepsis with higher-level TCs reporting a higher proportion of affected patients. Cook et al reported the same mean ICU and hospital length of stay (4.6 days) in the overall cohort.[33]

Nirula and Brasel aimed to determine whether functional outcomes differed among trauma centre levels in patients with minor injuries (ISS<9).[38] The odds of achieving independent feeding in penetrating trauma patients was higher in higher-level TCs compared to lower-level TCs (OR=2.5; 95% CI 1.1 to 5.2). Similarly, the odds of achieving good mobility was higher in higher-level TCs (OR=1.67; 95% CI 1.1 to 2.6). Functional scores were also more likely to be higher for penetrating trauma patients treated at higher-level TCs compared to lower-level TCs (OR=1.6; 95% CI 1.1 to 2.5).

Specific patient groups

Two studies were included: one on maternal trauma and the other on cirrhotic patients.[26,31] Both studies reported relevant outcomes and complications.

Distelhorst et al reported on maternal outcomes and complications after trauma.[26] Among the whole cohort, rates of placental abruption were higher in higher-level TCs (5.5%) compared to lower-level TCs (4.7%). Preterm labour (25.5%) and premature rupture of membranes (5.2%) were more frequently seen in higher-level TCs. Adjusted OR for preterm labour in higher-level TCs was 1.43 (1.15-1.79). Findings were similar among patients with ISS>9.

Bukur et al showed that a higher proportion of patients in higher-level TCs were taken to the operating room immediately compared to lower-level TCs.[31] A higher proportion of patients were admitted to ICU in lower-level TCs (31.8%) compared to level I (22.7%) or level II TCs (28.3%). Overall complications were higher in lower-level TC (8.4%) compared to either level I (7.4%) or level II TCs (5.3%).

DISCUSSION

In this current systematic review, we aimed to compare the mortality and trauma outcomes between lower-level and higher-level TCs.

Our meta-analysis revealed that patients with neurological trauma had a 20% (95% CI 14% to 27%) lower risk of death in lower-level TCs compared to higher-level TCs. Although we found no evidence of differences between TC levels for mortality in severely injured patients overall, the removal of one extreme study revealed a 25% (95% CI 2% to 53%) increase in the risk of death at lower-level versus higher-level TCs.[15] Death rates were also higher in lower-level TCs for severely injured patients in the two studies that were not included in the meta-analysis.[22,44] Otherwise, there was no evidence of a difference in the risk of death for paediatric patients or adult patients treated across the trauma system if they were treated at lower-level compared to higher-level TCs, although the large variation in results from the latter category preclude any meaningful interpretation.

Severe injuries and lower-level TCs: an unsafe combination

A higher risk of death for severely injured patients at lower-level TCs has been demonstrated in other studies.[16] Multiple explanations have been offered to explain this finding. Firstly, the volume of severely injured patients treated at higher-level TCs is much higher than in lower-level TCs across all the included studies and studies have shown that as the volume of trauma patients increases, mortality rates decrease.[7,15,45-47] The association between higher volume and increasing efficacy in surgical practice is well-known and this effect has been demonstrated across multiple surgical as well as trauma-related procedures.[48,49] A larger volume in higher-level TCs also allows for 'fine-tuning' of protocols and guidelines in trauma by drawing on the collective experiences of trauma specialists. Failure in complying with such protocols and guidelines at lower-level TCs is a possible reason for higher mortality rates at these centres.[45] Higher-level TCs also have a greater availability of resources and access to expertise – angio-intervention, for example, in treating haemorrhagic shock.[15] Level I and II TCs – by virtue of their designation – have access to tertiary care subspecialties, e.g. neurosurgery, which allows the multiply injured patient to be treated in one centre with input from relevant specialities, unlike in lower-level TCs where care for the severely injured patient may be compromised due to the non-availability of services.[50]

Failures in assessment, resuscitation, complying with guidelines, and obtaining specialist input were all key themes for improvement in an evaluation of an Australian trauma system.[51] To counter this, training through advanced trauma life support (ATLS) courses can significantly improve the knowledge of participants managing multiply injured patients and have been shown to improve processes of care in managing trauma patients at lower-level TCs.[52]

Alongside training, an emphasis on quality improvement activities is a key driver of efficacy in higher-level TCs and mortality rates have been shown to fall with the implementation of trauma quality improvement programs.[45,53,54] Developing such processes at lower-level TCs, where lacking, will be important to ensure that care for severely injured patients is optimised. The presence of a dedicated trauma service, to admit and care for all trauma patients, at lower-level TCs has been shown to reduce mortality in severely injured patients.[55] The feasibility of introducing such a service at low-volume TCs, however, is not wholly clear.

Neurological trauma and lower-level TCs: falsely reassuring data

The lower risk of death in lower-level TCs for patients with neurological trauma – both head and spinal - is notable. Fakhry et al contend that underestimation (or even overestimation) of the severity of head injury may contribute to the significant proportion of patients with severe head injury transported to lower-level TCs.[23] The influence of other co-morbidities and drug/alcohol intoxication limiting the assessment of these patients is also a contributing factor.[23] Clinicians' assessment of the Glasgow coma scale (GCS) is variable and can be influenced by the underlying pathology or the level of consciousness.[56] High-quality studies assessing its reliability are also limited in number.[57] GCS scoring was shown to be higher in elderly patients compared to matched pairs of younger patients with a similar severity of head injury, emphasising the difficulties in managing elderly patients with trauma.[58]

With respect to the elderly- a focus of Barmparas et al's study- there may be a tendency to underestimate the severity of illness in this population as they may not display the classical signs of physiological instability, which may inadvertently lead to undertriage to the wrong TC level.[25] Therefore, inaccurate triage and assessment of severe head injury patients may have contributed to inappropriate transfers while accurate data collection of the initial GCS on national databases (like the NTDB), on which many of the included studies are based on, can be adversely affected.

Nevertheless, mortality rates were higher at higher-level TCs in this meta-analysis. This effect is not particularly consistent across published studies. The mortality benefit of managing severely head injured patients at neurosurgical centres (and, by extension, at higher-level TCs) has been well-described, especially in the presence of a neurocritical care unit.[8,11,59,60]

Concomitant extracranial injuries play a significant role in determining outcome in head injury patients and studies have shown that mortality is higher when other injuries co-exist.[61] The burden of extracranial injuries at higher-level TCs are likely to be more extensive than at lower-level TCs and the influence of these injuries on the higher mortality at higher-level TCs in severe head injury patients is a key consideration in analysing our results. The mortality risk of operative interventions in neurosurgery for severe head injuries, for example, at higher-level TCs is also a relevant factor. Salvageability of some patients with severe head injuries can influence transfer to higher-level TCs or, conversely, the lack of it can pre-empt admission at lower-level TCs which can artificially inflate the mortality rates at either type of TC.

Mortality from spinal injuries was shown to be higher in higher-level TCs in this meta-analysis. As with severe head injuries, concomitant extraspinal injuries – as seen in patients at higher-level TCs – are common and they have a detrimental effect on mortality in patients with spinal cord injuries.[62] This effect is compounded in elderly patients, who were the focus of Barmparas et al's study, which can help explain the higher mortality seen in higher-level TCs.[25] Operative stabilisation for spinal fractures is also more likely to be performed at higher-level TCs and the risks of major spinal surgery can heighten the mortality risk at these TCs. Although more patients were operated in a timely manner at higher-level TCs in the Barmparas et al study, which has been shown to decrease morbidity, this doesn't seem to have had any major effect in reducing the risk of death at these TCs.[25,63]

Injured children and paediatric trauma centres

The meta-analysis did not show a significant difference in mortality between lower-level and higher-level TCs however the heterogeneity in the dataset limits any meaningful interpretations. Multiple studies have reported a significant reduction in mortality for injured children at paediatric trauma centres, when compared to adult higher-level TCs.[64,65]

Other studies have reported no such differences between paediatric trauma centres and higher-level adult TCs, after controlling for factors such as injury severity.[66,67] The financial burden of paediatric trauma limits the number of viable paediatric trauma centres however focused training, development of paediatric trauma teams, rapid transport to appropriate higher-level TCs, and dissemination of best practices to adult higher-level TCs could reduce the burden on paediatric trauma centres and help reduce mortality risk at higher-level TCs.[68]

Other outcomes and complications

We also compared other outcomes and complications of being treated at lower-level and higher-level TCs.

Four studies reported a longer length of stay at higher-level TCs, with three of these studies based on severely injured patients.[15,20,36,45] The increased severity of injuries and, thereby, complexity of care required at higher-level TCs indicates the lengthy rehabilitation period that may be necessary in these patients. Access to treatment differed between higher-level and lower-level TCs in severely injured patients with a longer delay in obtaining definitive care or surgery at lower-level TCs; patients with hip trauma were more likely to have a more expedient operation at MTCs than non-MTCs, for example.[15,42] These outcomes demonstrate the greater resource availability at higher-level TCs, e.g. theatre capacity or interventional radiology, which allow optimal care of the injured patient, particularly in the presence of medical co-morbidities.

Severely injured patients, patients with spinal cord injuries, hip trauma, and patients with head injuries were more often discharged home from lower-level TCs which reflects a less complex patient profile at these TCs.[23,25,42,45] Availability of rehabilitation services were not reported but better access to physiotherapy or related therapies at lower-level TCs compared to higher-level TCs may be of interest and needs further exploration. With respect to rehabilitation, independence with feeding and mobility after minor trauma was more likely to occur in patients treated at higher-level TCs, which helps underscore the importance of resources that are required to fully rehabilitate a trauma patient, even one with a minor injury.[38]

The higher proportion of injured patients treated at higher-level TCs in these studies, especially severely injured patients, as well as the longer length of hospital and intensive care stays, and injury or procedure-related sequelae helps account for the increased complication rates in this cohort of patients.[69,70]

Strengths and limitations

We have conducted a thorough and systematic review of the published literature to compare mortality, trauma-related outcomes, and complications between higher-level and lower-level TCs in the care of the injured patient. The meta-analysis performed in this study allows for objective appraisal of the published evidence, where it was not limited by heterogeneity. Study limitations include a reliance on studies utilising trauma registry data, e.g., NTDB, which are subject to various forms of bias, including selection bias. Missing data, variations in data collection and input between hospitals, and the voluntary nature of these registries are all significant confounders. Other limitations include a focus on studies published in the English language only. The studies included for meta-analysis, in general, demonstrated significant heterogeneity, limiting the clinical impact of these results.

CONCLUSION

In conclusion, this systematic review and meta-analysis identified a higher risk of death in patients with neurological trauma who were managed at higher-level TCs and this is likely to be due to the higher severity of injury (intracranial and extracranial) sustained by the patients at higher-level TCs. There was no significant difference in the risk of death for severely injured patients at either level of TC but, with one study excluded, a higher risk of death was identified on meta-analysis at lower-level TCs. Other outcomes of trauma care, such as length of stay and discharge destination, were more favourable in lower-level TCs. Complication rates were increased in higher-level TCs, especially in severely injured patients, reflecting the much more severe and complex disease profile that these patients have at higher-level TCs. However, the high level of heterogeneity within the evaluated studies limits any meaningful interpretations.

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