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Original Article

Risk-adjusted mortality in severely injured adult trauma patients in Sweden

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Abstract

Background: Risk-adjusted mortality (RAM) analysis and comparisons of clinically relevant subsets of trauma patients allow hospitals to assess performance in different processes of care. The aim of the study was to develop a RAM model and compare RAM ratio (RAMR) in subsets of severely injured adult patients treated in university hospitals (UHs) and emergency hospitals (EHs) in Sweden.

Methods: This was a retrospective study of the Swedish trauma registry data (2013 to 2017) comparing RAMR in patients (aged 15 years or older and New Injury Severity Score (NISS) of more than 15) in the total population (TP) and in multisystem blunt (MB), truncal penetrating (PEN), and severe traumatic brain injury (STBI) subsets treated in UHs and EHs. The RAM model included the variables age, NISS, ASA Physical Status Classification System Score, and physiology on arrival.

Results: In total, 6690 patients were included in the study (4485 from UHs and 2205 from EHs). The logistic regression model showed a good fit. RAMR was 4.0, 3.8, 7.4, and 8.5 percentage points lower in UH *versus* EH for TP ($P < 0.001$), MB ($P < 0.001$), PEN ($P = 0.096$), and STBI ($P = 0.005$), respectively. The TP and MB subsets were subgrouped in with (+) and without (−) traumatic brain injury (TBI). RAMR was 7.5 and 7.0, respectively, percentage points lower in UHs than in EHs in TP + TBI and MB + TBI (both $P < 0.001$). In the TP–TBI ($P = 0.027$) and MB–TBI ($P = 0.107$) subsets the RAMR was 1.6 and 1.8 percentage points lower, respectively.

Conclusion: The lower RAMR in UHs *versus* EH were due to differences in TBI-related mortality. No evidence supported that Swedish EHs provide inferior quality of care for trauma patients without TBI or for patients with penetrating injuries.

Introduction

Implementing regional and national systems in trauma care have been shown to reduce mortality and improve quality care[1]. Measurement and feedback of performance are integral parts of a trauma system. To measure trauma care performance requires validated risk-adjustment methods. Risk-adjusted mortality (RAM) after trauma is the comparison of the observed mortality to the predicted mortality calculated by a statistical model based on multiple predictors of trauma death (i.e. patient factors, injury severity, and patient physiology upon arrival). The rationale of risk adjustment is to remove sources of variation that are institutionally independent, with the goal that any residual differences reflect actual differences in the quality of care.

RAM has become the standard method for measuring and comparing hospital performance in trauma populations, and is widely used in North America and Europe[2–4]. The Norwegian survival prediction model in trauma (NORMIT) was developed from a single level 1 trauma centre population in Norway, and externally validated in Finnish[5] and Swedish (NORMIT and the recently updated NORMIT 2)[6] trauma populations. The NORMIT models demonstrated adequate prediction of mortality in Swedish trauma centre populations but performed poorly in mixed populations of patients admitted to all hospital types[5,6].

Mortality has declined along with the improvements introduced in trauma care in the last 20 to 30 years. Therefore, the usefulness of mortality as the only indicator of performance in a trauma population has been questioned[7], especially in less severely injured trauma populations with a low predicted mortality. As a tool for quality improvement, mortality in clinically relevant subsets of trauma patients, such as blunt multisystem injury, penetrating truncal injury, and traumatic brain injury (TBI), is measured in order to address different aspects of the trauma care process in the Trauma Quality Improvement Program (TQIP) implemented by the American College of Surgeons in 2006[8–11]. The subset approach acknowledges the heterogeneity in mortality inherent in a trauma population and comparisons of subsets allow each hospital to assess system performance from different aspects of the processes of care[11]. This is currently used in the Trauma Registry of the German Trauma Society[12] and in Trauma Audit and Research Network[13] in England and Wales.

Sweden has no uniform national organization for trauma care. There are concerns that the quality of trauma care will be affected by the ongoing regionalization and centralization of surgical care, and that the associated staff competences and hospital resources necessary for care of the trauma patient will be compromised. Therefore, measurements of hospital performance in trauma

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care in Sweden are urgently warranted. A recent Swedish study based on data from the National Trauma Registry (SweTrau) between 2013 and 2017 reported a 41 per cent (odds ratio for 1 month death 0.59) survival benefit for trauma patients treated at trauma centres *versus* non-trauma centres[14,15].

The aim of this study was to develop a prediction model of trauma mortality and to compare RAM ratio (RAMR) in clinically relevant subsets of severely injured adult trauma patients treated in university hospitals (UHs) and emergency hospitals (EHs) in Sweden.

Methods

The guideline for Transparent Reporting of multivariable Prediction model for Individual Prognosis or Diagnosis (TRIPOD) was used in the drafting of the study[15]. Reporting conformed to the STROBE statement guidelines for observational studies[16]. The study was approved by the Regional Ethical Review Board in Stockholm, Sweden (DNR2020-05039).

Study design and setting

This was a retrospective analysis of data obtained from SweTrau comparing RAMR between trauma patients in clinically relevant subsets treated in UHs and EHs in Sweden. Sweden is divided into 21 regions, each responsible for its own health care. Each region has a designated university hospital (seven in total) serving as a regional trauma centre; these are the only hospitals with neurosurgical and other subspeciality capabilities. An EH is defined as a hospital that can perform emergency surgery 24 hours a day, 7 days a week, with available senior competence in anaesthesia, surgery, orthopaedics, internal medicine, and radiology and laboratory resources. The trauma patient load to UHs varies and may not reach the more than 1200 patients per year or more than 240 patients per year with an Injury Severity Score over 15 required by the American College of Surgeons Committee of Trauma for a level 1 trauma centre. Candefjord *et al.*[14], investigated the same trauma population as the current study, and showed that the mean number of patients treated at trauma centres (eqvivalent to UHs in the current study) were 734 patients per year and for non-trauma centres (equivalent to EHs) 331 patients per year.

The National Trauma Registry

The inclusion criteria in SweTrau have been described previously[6]. The registry is based on the revised Utstein Trauma Template, which is the current European core dataset[17], and has registered patients in Sweden since 2011.

Inclusion criteria for the present study

Severely injured (New Injury Severity Score (NISS) greater than 15), adult (aged 15 years or older) trauma patients who were primarily admitted or transferred to the reporting hospital between 1 January 2013 and 31 December 2017, for whom survival status up to 30 days after the injury was known, were included. Extracted data were anonymized to ensure the confidentiality of patients, physicians, and participating hospitals. Patients were excluded if 30-day mortality could not be determined (patients without a Swedish social security number). A Glasgow Coma Scale (GCS) score of 3, a respiratory rate (RR) of 0, and a systolic blood pressure (SBP) of 0 on admission were used as a proxy definition to exclude patients who were dead on arrival[18,19]. Patients with missing data for the different components of the prediction model were imputed and not excluded.

Study populations

The study population was comprised of all patients registered in SweTrau who fulfilled the inclusion criteria for this study. Definitions of the three subsets of patients were 'MB', multisystem blunt injury (blunt mechanism with Abbreviated Injury Scale (AIS) of 3 or more in at least two of the following AIS body regions—head, face, neck, thorax, abdomen, spine, and upper or lower extremities); 'PEN', truncal penetrating injury (penetrating mechanism with injuries of AIS 3 or more in at least one of the following AIS body regions—neck, thorax, or abdomen); 'STBI' (prehospital GCS less than 9 and at least one AIS 3 or more in AIS Body Region Head). The MB and PEN subsets were classified according to the original TQIP definitions[9], and the STBI subset adapted from Hornor *et al.*[10]. The total population (TP) and MB subset were further divided into subgroups based on the presence of a TBI, defined as AIS 3 or more in the Body Region Head.

Coding, scoring, and outcome

Anatomical injury severity was scored by Association for the Advancement of Automotive Medicine-certified registrars according to AIS 2005-update 2008 (AIS 2008)[20]. Physiological derangement on arrival was classified according to the triage-revised trauma score (T-RTS)[21] defined as 0.9368 GCS + 0.7326 SBP + 0.2908 RR, and based on hospital admission vital signs[22]. For patients arriving intubated and under general anaesthesia, RR and GCS were scored based on vital signs documented immediately prior to intubation. The NISS categories 16 to 24, 25 to 34, and 50 to 75 of injury severity were used[23], and age was presented in age intervals of 15 to 45, 46 to 65, 66 to 80, and over 80 years. The outcome was defined as death at 30 days after injury, regardless of whether the patient was discharged from the hospital within this time frame.

Calculation of mortality ratios

Data were presented as observed mortality ratio (OMR), expected mortality ratio (EMR), overall mortality ratio (OAM) and RAMR. OMR was calculated by using the observed (actual) deaths in the total population and in subsets as the nominator and the number of patients being treated at UHs and/or EHs as the denominator. EMR was calculated by using expected (predicted by the risk-adjustment model) deaths as the nominator and the number of patients being treated at UHs and/or EHs as the denominator. OAM was the mortality ratio in the group being investigated, with deaths as the nominator and the total number of patients in the denominator (i.e. the total population or MB, PEN, or STBI subsets). RAMR was calculated by multiplying the OMR/EMR with OAM.

Statistical methods

Data are presented as median (range) and differences between categorical variables were evaluated using Pearson's χ^2 test (asymptotic significance two-sided). For the differences between hospital types, standard errors, confidence intervals (c.i.), and *P* values were calculated from the normal approximation to the binomial distribution. For the prediction model, data were analysed with logistic regression. The prediction model calculated expected deaths and was based on the previously described NORMIT[22] but was adapted by including variables in other forms in order for them to be applicable to the Swedish trauma population treated in both EHs and UHs. For age, AGE + AGE^2

Table 1 Descriptive statistics of the study population

Variable	Total population ($n = 6690$)	University hospitals ($n = 4485$)	Emergency hospitals ($n = 2205$)	P*
Trauma type				<0.001
Motor vehicle crash	1091 (16.3)	628 (14.0)	463 (21.0)	
Motorcycle	691 (10.3)	464 (10.3)	227 (10.3)	
Bicycle	511 (7.6)	350 (7.8)	161 (7.3)	
Traffic, pedestrian	292 (4.4)	206 (4.6)	86 (3.9)	
Traffic, other	112 (1.2)	74 (1.6)	38 (1.7)	
High fall (>3 m)	1790 (26.8)	1193 (26.6)	597 (27.1)	
Low fall (<3 m)	981 (14.7)	685 (15.3)	296 (13.4)	
Gunshot wound	207 (3.1)	179 (4.0)	28 (1.3)	
Stabbing	325 (4.9)	241 (5.4)	84 (3.8)	
Blunt object	414 (6.2)	307 (6.8)	107 (4.9)	
Other	209 (3.2)	102 (2.3)	107 (4.9)	
Unknown	67 (1.0)	56 (1.2)	107 (0.5)	
Age intervals (years)				<0.001
15–45	2627 (39.3)	1862 (41.5)	765 (34.7)	
46–65	2022 (30.2)	1374 (30.6)	648 (29.4)	
66–80	1370 (20.5)	865 (19.3)	505 (22.9)	
>80	312 (10.0)	384 (8.6)	287 (13.0)	
NISS intervals				<0.001
16–24	3420 (51.1)	2098 (46.8)	1322 (60.0)	
25–34	1927 (28.8)	1323 (29.5)	604 (27.4)	
35–49	740 (11.1)	564 (12.6)	176 (8.0)	
50–75	603 (9.0)	500 (11.1)	103 (4.6)	

*Statistical comparisons using the Chi2-test was made in the crosstabs table for each variable (trauma type, age intervals and NISS intervals) between University and Emergency hospitals.

(NORMIT used AGE^3 as sole representation of age) was used. No interaction between NISS and ASA Physical Status Classification System Score (ASA-PS) was found, contrary to NORMIT. Thus, the risk-adjustment model was logit(30-day death) ∼ RTS + AGE + AGE^2 + NISS + ASA-PS. RTS, AGE, AGE^2, and NISS were used as continuous variables and ASA-PS was categorical. Missing values were multiply imputed using chained equations based on prehospital RTS and the variables included in the logistic regression. The model's discrimination and calibration capacity were evaluated using the bootstrap technique to delineate internal validity and the degree of predictive optimism, as well as the analysis of residuals to determine how well the models fit the underlying data. Subsets were analysed by direct comparisons of RAM between different subsets and hospitals types. OMR, EMR, and RAMR in the subsets are shown in fractions and differences in fractions with confidence intervals, and discussed as percentages and differences in percentage points in comparisons between the two hospital types. These two hospital types were equated with two different 'treatments': UH treatment and EH treatment, and differences were also illustrated with numbers needed to treat to save one life based on mean difference and lower and upper confidence intervals.

Results

Total population

A total of 47 050 patients were collected from the registry of whom 7097 matched the inclusion criteria. The included patients were registered from 29 hospitals: seven UHs (two UHs have two emergency departments with trauma patients triaged to one site) and 20 EHs. Excluded were 397 patients lost to follow-up and 10 patients who were dead on arrival were excluded. Of the 6690 patients included in the study, 4485 (67.0 per cent) were treated in a UH. Median age was 52 (15 to 103) years in the total population, and was lower in patients treated in UH *versus* those treated in an EH (51 (15 to 99) *versus* 56 (15 to 103) years) ($P < 0.001$). Overall, 4883 were male (73.0 per cent), with more males in the UH *versus* EH population (74.0 *versus* 71.0 per cent; $P = 0.009$). The distribution of injury mechanism, age, and NISS in the total population is shown in *Table 1*. The largest differences between hospital types were fewer injuries related to motor vehicle crashes (14.0 *versus* 21.0 per cent) and more shootings and stabbings in UHs *versus* EHs (4.0 *versus* 1.3 per cent and 5.4 *versus* 3.8 per cent, respectively). Patients treated at UHs were younger and more severely injured than patients treated at EHs.

Clinical subsets

Of all patients, 3863 (57.7 per cent) were included in one of the three subsets: MB (2638 patients (1827 at UHs; 811 at EHs)); PEN (375 patients (273 at UHs; 102 at EHs); and STBI (850 patients (640 at UHs; 210 at EHs)). Median age was 55 (15 to 103), 30 (15 to 88), and 53 (15 to 98) years in the MB, PEN, and STBI subsets, respectively ($P < 0.001$). The proportion of male sex was 71.9 per cent (1930 patients) in the MB, 90.4 per cent (339 patients) in the PEN, and 70.6 per cent (600 patients) in the STBI subset ($P < 0.001$). When comparing age according to the four age intervals in the MB and STBI (excluding PEN) subsets, differences were apparent between UHs and EHs. In the MB subset, more patients were aged 15 to 45 years (35.5 *versus* 33.3 per cent) and 46 to 65 years (33.9 *versus* 30.7 per cent), and fewer were aged 66 to 80 years (22.2 *versus* 24.0 per cent) and over 80 years (8.4 *versus* 12.0 per cent) for UHs *versus* EHs, respectively (all $P = 0.012$). In the PEN subset, a higher proportion of young patients (aged 15 to 45 years) was observed (79.5 and 75.5 per cent, respectively, at UHs *versus* EHs), and no other differences were observed in the age intervals between hospital types. The STBI subset had the highest proportion of patients over 80 years of age (11.4 *versus* 16.2 per cent at UH *versus* EH; for 15–45 years 44.5 *versus* 30.0 per cent, for 46–65 years 25.0 *versus* 29.5 per cent, and for 66–80 years 19.1 *versus* 24.3 per cent (all $P = 0.020$)).

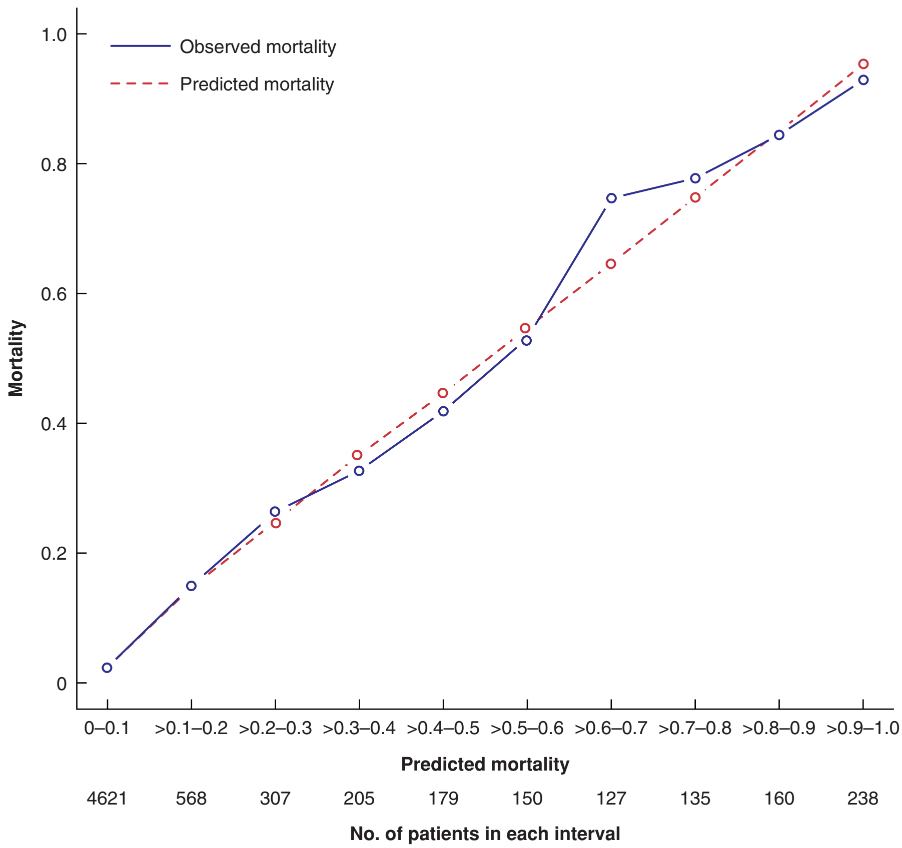

Fig. 1 Observed and predicted mortality by 1/10 intervals of predicted mortality in the model population

Parallel lines indicate a good fit of the model.

For all subsets, more severe injuries were observed at UHs *versus* EHs, with a lower proportion of patients in the two lower NISS categories and a higher proportion of patients in the two highest NISS categories at UHs. In the MB subset, the proportion of patients in the four NISS categories treated at UHs *versus* EHs were as follows: NISS 16–24, 32.1 *versus* 41.8 per cent; NISS 25–34, 39.1 *versus* 39.7 per cent; NISS 35–49, 19.3 *versus* 13.8 per cent, and NISS 50–75, 9.5 *versus* 4.7 per cent (all $P < 0.001$). In the PEN subset, the proportion of patients in the four NISS categories treated at UHs *versus* EHs were as follows: NISS 16–24, 41.0 *versus* 51.0 per cent; NISS 25–34, 31.1 *versus* 35.3 per cent; NISS 35–49, 12.8 *versus* 9.8 per cent; and NISS 50–75, 15.1 *versus* 3.9 per cent (all $P = 0.016$). In the STBI subset, more severe injuries were observed in UHs *versus* EHs patients with the proportion of patients of NISS 16–24 being 9.4 *versus* 19.0 per cent; those of NISS 25–34 being 33.3 *versus* 43.8 per cent; those of NISS 35–49 being 21.4 *versus* 16.7 per cent; and those of NISS 50–75 being 35.9 *versus* 21.0 per cent (all $P < 0.001$).

In the 2827 patients not included in any subset, injury severity was markedly lower compared to the three clinically defined subsets (MB, PEN, and STBI). Some 95.4 per cent of the patients had a NISS of less than 35 in the excluded population *versus* 79.9 per cent included in one of the three subsets.

Observed mortality ratio

The OMR in the total population was 15.7 per cent (1048 patients), and there was no significant difference between patients treated in UHs compared with EHs, either in the total population or in the subsets (*Tables S1–S4*), apart from the subgroup of the total population with a TBI (*Table S1*). In the three subsets, the highest mortality was observed in the STBI subset (49.6 per cent), followed by PEN (20.0 per cent) and MB (10.4 per cent). The high mortality in the STBI subgroup indicated that STBI contributed substantially to the total mortality in the investigated population. Therefore, a subgrouping of patients with and without TBI was performed in the total population, as well as in the MB subset, in order to delineate the impact of TBI on observed (and risk-adjusted) mortality. Of all deaths in the total population, 704 deaths (67.2 per cent) occurred in patients with a TBI. No subgrouping was performed in the PEN group due to the very low number of patients with TBI in this group (12 of 350 patients).

When the total population was subgrouped into with *at least one* (+) and *without any* (–) TBI and then compared between hospitals, a more than twofold increase in OMR was found in the TP + TBI group *versus* TP–TBI, and there was a 4.9 percentage point difference between hospital types in favour of UH for patients with TBI but not without TBI (*Table S1*). Similarly, in the MB–TBI group there were no differences between hospital types in patients without TBI; however, for patients with a TBI, the difference in observed mortality was 7.0 percentage points (*Table S2*).

Risk adjustment model

The logistic regression model showed a concordance of 0.930 and bootstrap showed good validation of the model. The comparison of observed and predicted mortality by 1/10 intervals of predicted mortality demonstrated a good fit aside for the interval of more than 0.6–0.7 (*Fig. 1*). This interval also had the least number of patients (127 patients) of the intervals. Missing

Table 2 Risk-adjusted mortality ratio (RAMR) in university hospitals (UHs; $n = 4485$) and emergency hospitals (EHs; $n = 2205$)

	TP ($n = 6690$)	MB ($n = 2638$)	PEN ($n = 375$)	STBI ($n = 850$)
UH RAMR (95% c.i.)	0.144 (0.137–0.152)	0.080 (0.070–0.090)	0.227 (0.199–0.254)	0.481 (0.452–0.511)
EH RAMR (95% c.i.)	0.185 (0.173–0.197)	0.117 (0.102–0.133)	0.301 (0.218–0.384)	0.566 (0.515–0.618)
RAMR Diff (95% c.i.)	−0.040 (−0.054 to −0.027)	−0.038 (−0.056 to −0.019)	−0.074 (−0.162 to 0.013)	−0.085 (−0.145 to −0.025)
P value (Diff)	0.001	0.001	0.096	0.005

TP, total population; MB, multiple blunt trauma; PEN, penetrating truncal trauma; STBI, severe traumatic brain injury.

Table 3 Risk-adjusted mortality ratio (RAMR) in total population and in the MB subset subgrouped in patients with (+) and without (−) traumatic brain injury (TBI) in university hospitals (UH) and emergency hospitals (EH)

	TP + TBI ($n = 2985$)	TP-TBI ($n = 3705$)	MB + TBI ($n = 1250$)	MB-TBI ($n = 1388$)
UH RAMR (95% c.i.)	0.221 (0.208–0.234)	0.083 (0.075–0.090)	0.097 (0.081–0.114)	0.064 (0.052–0.076)
EH RAMR (95% c.i.)	0.296 (0.274–0.318)	0.099 (0.087–0.111)	0.167 (0.139–0.196)	0.082 (0.064–0.099)
RAMR Diff (95% c.i.)	−0.075 (−0.100 to −0.049)	−0.016 (−0.030 to −0.002)	−0.070 (−0.103 to −0.038)	−0.018 (−0.039 to 0.004)
P value (Diff)	0.001	0.027	0.001	0.107

TP, total population; MB, multiple blunt trauma.

data values to calculate hospital RTS (GCS, SBP, or RR; 2624 patients) were multiple imputated using prehospital values. Missing ASA values (173 patients, 2.6 per cent) were imputated based on age and sex.

Risk-adjusted mortality ratio

RAMR was a calculated comparison between patients with similar risk profiles (for death) between hospital types. The comparisons of observed mortality (O) and expected (calculated) mortality ratio (E), O/E ratios, and RAMR for the total population and MB with and without TBI are shown in *Tables S1 and S2* and for the PEN and STBI subsets in *Tables S3 and S4*. RAMR and differences between hospital types are shown for the total population, the MB, PEN, and STBI subsets, and for the total population, and for the MB subset subgrouped into with and without TBI both in *Tables 2 and 3*, respectively, as well as in *Tables S1–S4*. The difference in RAMR in the total population between UH and EH was 4.0 percentage points in favour of treatment at the UH (14.5 *versus* 18.5 per cent; $P < 0.001$) (*Table 2*). When the TP was grouped (−) and (+) TBI and then compared between hospitals, the difference in RAMR was 7.5 percentage points for the TP + TBI between UH *versus* EH (22.1 *versus* 29.6 per cent; $P < 0.001$) and for the TP–TBI, the difference was 1.6 percentage points with RAMR of 8.3 *versus* 9.9 per cent at UH *versus* EH ($P = 0.027$) (*Table 3*).

For the MB subset, there was a 3.8 percentage point lower RAMR in the UH *versus* EH ($P < 0.001$) (*Table 2*). The difference in RAMR for the MB subset between hospital types was compared in groups (+) and (−) TBI; there were no significant differences between UH and EH for MB–TBI (6.4 *versus* 8.2 per cent; $P = 0.107$). In the MB subset + TBI, the difference was 7.0 percentage points between hospitals (9.7 *versus* 16.7 per cent; $P < 0.001$) (*Table 3*).

For the PEN subset there were no significant differences in mortality, although there was a 7.4 percentage point lower RAMR in UH *versus* EH ($P = 0.096$) (*Table 2*). The largest difference in RAMR between hospital types was observed in the STBI subset with a difference of 8.5 percentage points ($P = 0.005$) in favour of treatment at UH (48.1 *versus* 56.6 per cent at UHs and EHs, respectively) (*Table 2*).

Discussion

In this multicentre observational study of severely injured adult trauma patients, RAM was analysed in the total study population and in clinically relevant subsets in UH and EH. The differences in RAM were most impressive for the STBI and PEN subsets, but the difference for PEN was not significant. When severe TBI was excluded from the total population and the MB subset, the differences between UH and EH diminished, but when severe TBI was included, the differences increased. These findings suggest that UH outperforms EH when it comes to the treatment of TBI, but the difference in outcome following treatment of extracranial injury appears to be more uniform. The prediction model based on logistic regression showed good discrimination and calibration. It also predicted death accurately in the TP, and MB and STBI subsets.

An important finding in the current study is that the major cause for the differences in RAM between hospital types appeared to be due to differences in deaths in patients with TBI. TBI is a major cause of injury-related deaths, as demonstrated in a large European epidemiological study in which TBI-related age-adjusted mortality accounted for 37 per cent of all the injury age-adjusted mortality[24]. The 7.5 and 7.0 percentage point-reduced RAMR for patients treated in the UH in the TP and MB subset, respectively, in patients with TBI indicated institutional differences in the quality of care. As few as 13 trauma patients of the TP with a TBI or 14 MB + TBI patients needed to be treated at a UH, in order to gain one extra survivor *versus* treatment at an EH. However, EHs cannot be expected to have the same quality of TBI treatment and care as UHs owing to the lack of neurosurgical competence and neurointensive care. Therefore, a higher RAM for patients with TBI at an EH can be argued to be an expected finding. Furthermore, the higher RAM in EHs could have been influenced by a selection bias; patients with a higher mortality risk ineligible for transport to neurosurgical care and subsequently treated in the EH would lead to an increased mortality ratio. Age and ASA grade, which are dominating factors in the clinical decision-making for transfer to neurosurgical units, were included in the risk-adjustment model, yet other patient factors such as frailty, comorbidity not reflected in ASA, and anticoagulation medication could have shifted mortality in favour of a UH. Moreover, failures in the processes of care important for survival in TBI, such as rapid CT scan for diagnosis, emergency decompression of intracranial haemorrhage, adequate oxygenation and circulation, and a rapid transfer to a UH for definite care, are factors that may also have contributed to the increased mortality ratio in EH patients with TBI in the current study. Therefore, the findings warrant a local review of the trauma care processes for injured trauma patients with a TBI in all Swedish hospitals. The review process should be performed at a hospital and regional level to uncover opportunities for improvement in this complex trauma care process (from prehospital triage to rehabilitation).

The difference in RAMR between UH and EH was much smaller than what has previously been reported[14], and may have several explanations. Firstly, the data are presented differently, with percentage and difference in percentage points in the current study, and with odds ratios in the previous study, reducing the comparability. Secondly, the precision of this model may have been superior as the overall mortality in the current population was 3–4 times higher due to the exclusion of patients with a NISS of 15 or less. Thirdly, the model was adjusted for ASA and physiology on arrival, which are variables shown to have a major impact on trauma mortality[5,22,25]. Fourthly, differences in the imputation technique of missing data in the risk-adjustment models used may have affected the results. To facilitate comparisons of RAM, mortality ratios should be presented using absolute percentages and differences between institutions in percentage points as it gives a more accurate representation of the actual mortality ratio and is easier to interpret.

The observed mortality was not statistically different between hospitals and was comparable to previous reports in populations of severely injured patients in Germany (18.9 per cent)[26], Norway (13.8 per cent)[27], and Finland (13.0 per cent)[5]. In the MB subset, the observed mortality ratios of 9.4 and 12.7 per cent, for UH and EH, respectively, were in line with reports from the TR-DGU report 2020 (12.4 per cent)[28] and from the TQIP in USA (13.9 per cent)[29]. For the PEN subset, the observed mortality ratio of 22.0 and 14.0 per cent, for UH and EH respectively, was higher compared to TQIP registry data, with an observed mortality rate of 15.5–16.5 per cent[29,30]. This could have been influenced by the low number of patients in the PEN subset *versus* the TQIP database, which included more than 40 000 patients with penetrating injuries.

In the STBI subset, the observed mortality was 10 to 20 percentage points higher (47.2 and 57.1 per cent for UH and EH, respectively) than the 33 to 37 per cent observed mortality reported from the TQIP data from 2009 to 2011[31] and 2011 to 2013[32] using the same STBI definition. However, in the TR-DGU registry from the past 10 years, a similar mortality rate of 45.5 per cent was found in patients fulfilling the STBI criteria (personal communication Prof. Rolf Lefering, Working Group in TR-DGU, 9 September 2021). The GCS score of less than 9 in the STBI subset was most likely caused by the TBI, but haemorrhagic shock and/or hypoxia may have contributed to the low GCS and further increased mortality in this subset. However, the mortality ratio in the STBI subset increased in parallel to an increasing AIS score for Region Head and the first ICD-10 diagnosis was a brain injury diagnosis in the majority at UH and EH, respectively, indicating that TBI was the dominating type of injury, and thus the most likely cause of death. Not unexpectedly, a majority of the patients in the STBI group were treated in UH. The comparisons between hospital types suggest that only 12 patients were needed to treat with UH treatment to save one life. However, as few as seven patients (or up to 40 patients) could be enough to gain one survivor. These results demonstrate that the STBI subset represents patients with a very high mortality ratio in need of specialized care, which needs to be further characterized before mortality can be fully interpreted.

An O/E ratio of less than 1 implies a better-than-expected institutional performance and, in the present study, the O/E ratios indicated that UHs performed better than expected in all subsets other than the PEN group. In the PEN group, the O/E ratio indicated that both UHs (1.13) and EHs (1.50) underperformed (with no difference between hospital types) and thus had more deaths than expected. For the RAM, the opposite pattern was observed, with more deaths in the EHs for the PEN subset than in UHs. To summarize, risk prediction in the PEN subset did not show a good fit, indicating that a variable for predicting death in the model was missing for patients with penetrating trauma and/or that the sample group may have been too small, especially in EH. Penetrating trauma is often associated with haemorrhagic shock which requires immediate access to surgery and massive transfusion at the nearest hospital before a possible transfer to a trauma centre. Differences in these processes of care, which are difficult to adjust for and were not applied in the current study, may have major effects on outcome. Even though the PEN subset was relatively small, the results did not suggest that treatment was inferior in EHs compared to UHs for patients with penetrating injuries. However, the high observed mortality and RAMR demonstrates that continuous education in damage-control surgery and resuscitation is essential in both UH and EH in Sweden.

This study had several limitations. Firstly, the quality of data must be considered. Validation to assure data quality and data completeness of SweTrau is performed against the Swedish Intensive Care Register[33], but no validation was performed from 2013 to 2017. Secondly, the uneven coverage of the trauma registry limits the applicability of the results to all Swedish hospitals. The majority of patients in the current study were from UHs, and 22 hospitals did not report data to SweTrau during the study period[14]. However, admission of trauma patients with a NISS greater than 15 was most likely low in more than half of these hospitals (13 of 22); three were located in the Stockholm region with a well-established prehospital triage of severely injured trauma patients to the regional UH and nine were in the process of becoming an elective hospital during the study period due to the regionalization of surgical care. Two hospitals are remote hospitals in the Northern part of Sweden with a low trauma patient load. Thirdly, potential structural and geographical differences between Swedish regions, as well as hospital transfers within and outside regions, were not taken into consideration but may have influenced the results.

The differences in RAM between UH and EH were due to differences in TBI-related mortality and warrant a clinical review of the processes of care for severely injured adult trauma patients with TBI in Sweden. The current study found no evidence that Swedish emergency hospitals provide inferior quality of care for trauma patients without TBI or for patients with penetrating injuries.

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Supplementary material

Supplementary material is available at *BJS Open* online.

Data availability

Due to ethical concerns, supporting data cannot be made openly available. Further information about the data and conditions for access are available at the National Trauma Registry website https://rcsyd.se/swetrau/.

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