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Comparison of Intensive Care and Trauma-specific Scoring Systems in Critically Ill Patients

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ABSTRACT

Introduction: Amongst critically ill trauma patients admitted to ICU and still alive and in ICU after 24 hours, it is unclear which trauma scoring system offers the best performance in predicting in-hospital mortality.

Methods: The Australia and New Zealand Intensive Care Society Adult Patient Database and Victorian State Trauma Registry were linked using a unique patient identification number. Six scoring systems were evaluated: the Australian and New Zealand Risk of Death (ANZROD), Acute Physiology and Chronic Health Evaluation III (APACHE III) score and associated APACHE III Risk of Death (ROD), Trauma and Injury Severity Score (TRISS), Injury Severity Score (ISS), New Injury Severity Score (NISS) and the Revised Trauma Score (RTS). Patients who were admitted to ICU for longer than 24 hours were analysed. Performance of each scoring system was assessed primarily by examining the area under the receiver operating characteristic curve (AUROC) and in addition using standardised mortality ratios, Brier score and Hosmer-Lemeshow C statistics where appropriate. Subgroup assessments were made for patients aged 65 years and older, patients between 18 and 40 years of age, major trauma centre and head injury.

Results: Overall, 5,237 major trauma patients who were still alive and in ICU after 24 hours were studied from 25 ICUs in Victoria, Australia between July 2008 and January 2018. Hospital mortality was 10.7%. ANZROD (AUROC 0.91; 95% CI 0.90-0.92), APACHE III ROD (AUROC 0.88; 95% CI 0.87-0.90), and APACHE III (AUROC 0.88; 95% CI 0.87-0.89) were the best performing tools for predicting hospital mortality. TRISS had acceptable overall performance (AUROC 0.78; 95% CI 0.76-0.80) while ISS (AUROC 0.61; 95% CI 0.59-0.64), NISS (AUROC 0.68; 95% CI 0.65-0.70) and RTS (AUROC 0.69; 95% CI 0.67-0.72) performed poorly. The performance of each scoring system was highest in younger adults and poorest in older adults.

Conclusion: In ICU patients admitted with a trauma diagnosis and still alive and in ICU after 24 hours, ANZROD and APACHE III had a superior performance when compared with traditional trauma-specific scoring systems in predicting hospital mortality. This was observed both overall and in each of the subgroup analyses. The anatomical scoring systems all performed poorly in the ICU population of Victoria, Australia.

Introduction

Major trauma is a significant cause of morbidity and mortality in Australia with 12,647 trauma-related deaths in Australia in 2015, representing 8.1% of total mortality. This proportion has remained unchanged since the year 2000 [1–3]. Trauma patients admitted to ICU in Australia have increased in age between 2005 and 2017 and they have an increased burden of chronic disease [4].

Multiple trauma scoring systems have been described which can be used to grade the severity of trauma and predict morbidity and mortality outcomes [5–8]. These include anatomical scor-

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ing systems such as the Injury Severity Score (ISS) and physiologic systems such as the Revised Trauma Score (RTS) [9–11]. Combination systems such as the Trauma and Injury Severity Score (TRISS) have sought to leverage the advantages of both systems [12]. These trauma-specific scoring systems are described in detail in Appendix 5 (supplementary digital content).

As a consequence of their injuries, many major trauma patients are critically ill and require admission to intensive care. As for other critical illnesses, a number of generic critical care scoring systems are applied to trauma patients, such as the Acute Physiology and Chronic Health Evaluation (APACHE III) score [13] and the Australia and New Zealand Risk of Death (ANZROD), which can also be applied to trauma patients. The Australia and New Zealand Risk of Death (ANZROD) was developed in 2013, by customisation of the APACHE III score to the Australian and New Zealand population. It had better overall discrimination and calibration for predicting mortality in Australia and New Zealand than APACHE III [14,15]. ANZROD and APACHE III ROD give a predicted risk of death for each patient [16,17].

The Victorian State Trauma System was established in Victoria in 2001 and has the most comprehensive trauma registry in Australia [18,19]. There are two designated adult major trauma centres, and state-wide trauma triage and transfer protocols guide the transfer of injured patients to the appropriate destination [3].

Amongst critically ill major trauma patients in Australia, it is unclear to what extent the addition of physiological variables improves the prediction of hospital mortality in patients admitted to ICU with a trauma diagnosis. The Injury Severity Score is currently used as part of the definition of major trauma in Victoria and in many other trauma systems in the world [18,20], but the performance of this anatomical scoring system in ICU patients is unknown. Trauma registry and critical care registry data in Victoria were linked to evaluate and compare the predictive capacity for hospital mortality of the ANZROD, APACHE III risk of death, TRISS, ISS, NISS and RTS in ICU patients admitted with a trauma-related diagnosis.

Methods

ANZICS-APD is a binational database that records demographic, severity of illness, and in-hospital outcome data of admissions to adult ICUs in Australia and New Zealand. It is run by the ANZICS Centre for Outcome and Resource Evaluation clinical quality registry and presently contains over 2.5 million patient records [21]. The VSTR database has been collecting data about all hospitalised major trauma patients in Victoria since July 2001 and collects routine in-hospital outcomes including mortality, length of stay, complications and discharge destination [18].

Trauma patients unable to be matched between databases were excluded from the analysis. In view of the ANZROD and APACHE III scores determining mortality risk based on the worst physiological variables in the first 24 hours of ICU stay, patients who were admitted to ICU and remained in ICU for less than 24 hours were excluded from the analysis. The analysis was restricted to patients who did not require inter-hospital transfer. Intensive Care Units were classified into one of four categories based on hospital type: tertiary, metropolitan, rural and private.

The scoring systems assessed were ANZROD, APACHE III (score and its associated predicted risk of death), TRISS, ISS, NISS and RTS. Baseline characteristics were analysed by survival status. Both ANZROD and APACHE III were calculated using the 'worst' acute physiological or biochemical values during the first 24 hours following ICU admission. The performance of each scoring system was also assessed in four subgroups: older adults (65 years and older), younger adults (between 18 and 40 years of age), major trauma centre (yes/no) and head injury (yes/no). Patients who were admitted to one of the two adult Victorian state trauma centres were defined as being managed in a major trauma centre. Head injured patients were identified using the ANZICS-APD diagnostic code for trauma, "head injury with multi-trauma" and "head injury without multi-trauma".

Statistical Analysis

Results were reported as frequencies and percentages, means with standard deviations (SDs), or medians with interquartile range (IQRs) in accordance with the underlying distribution. Data were assessed for normality, and groups compared using chi-squared test for equal proportion, independent t, or Wilcoxon rank-sum tests as appropriate. Patients with missing data were excluded from the analysis. All analyses were performed in STATA version 15.0.

The discrimination of each scoring system was assessed by computing the area under the receiver operating curve (AUROC). Receiver operating characteristic (ROC) curves for different scoring systems were compared using a chi-square tests with results presented as differences (95%CI). An AUROC of between 0.5 and 0.7 was considered poor discrimination; an AUROC of 0.7 to 0.8 was considered acceptable discrimination; an AUROC of 0.8 to 0.9 was considered excellent discrimination and an AUROC of $\geq$ 0.9 was considered outstanding discrimination.

Calibration was assessed in the following ways: Standardised mortality ratios (with associated 95% confidence intervals) were calculated for ANZROD, APACHE III ROD and TRISS by dividing the observed number of deaths by the total number of predicted deaths derived from each scoring system. The goodness-of-fit C statistic of Hosmer and Lemeshow (H–L C statistic) was estimated for ANZROD, APACHE III and TRISS [22]. This measures how closely the predicted and observed mortality coincide in ten equally sized subgroups of increasing severity. A well calibrated score receives low values in the H–L statistic, which is not significantly different from zero. A Brier score was calculated for ANZROD, APACHE III and TRISS. This measures the averaged squared difference between the observed and predicted in-hospital mortality.

Ethical Approval

The study was approved by the Alfred Hospital Ethics Committee (approval number: 631/17).

Results

Between July 2008 and January 2018, 9,800 patients admitted to 25 ICUs in Victoria, Australia with a trauma diagnosis were identified from the ANZICS-APD database. There were 895 (9.0%) trauma patients unable to be linked between the ANZICS-APD and VSTR datasets. The baseline characteristics of these patients are outlined in Appendix 2. The mortality rate of unmatched patients was higher (26.0%) than that for the patients in the matched dataset (10.7%). In addition, 690 patients (7.0%) did not have complete data for every scoring system so were excluded from the final analysis (Appendix 1). Patients who died or were discharged from ICU within 24 hours (691 patients; 7.1%) and patients who required interhospital transfer (2332 patients; 23.8%) were also excluded. The final analysis included 5,237 ICU trauma patients. Major trauma centre admissions accounted for 4,546 patients (86.8%).

Baseline Characteristics

Table 1 outlines the baseline characteristics in hospital survivors and non-survivors. The mean (SD) age of ICU trauma patients was 47.9 (20.8) and the average age increased from 45.2

Table 1
Baseline characteristics of ICU trauma survivors and non-survivors.

	Overall (n=5237)	Non-Survivors (n=561)	Survivors (n=4676)
Age (SD)	47.9 (20.8)	62.9 (20.7)	46.1 (20.1)
Male sex (%)	3897 (74.4)	422 (75.2)	3475 (74.3)
Ventilated (%)	3554 (67.9)	476 (84.9)	3078 (65.9)
Died in ICU (%)	408 (7.8)	408 (72.7)	-
ICU length of stay in days (IQR)	4 (2-9)	4 (2-8)	4 (2-9)
Admitted to a major trauma centre (%)	4546 (86.8)	471 (84.0)	4075 (87.1)
Median GCS (IQR)	13 (8-15)	6 (3-12)	14 (9-15)
Chronic medical condition (%)	264 (5.0)	78 (13.9)	186 (4.0)
Median ANZROD (IQR)	2.7 (0.9-11.6)	36.9 (16.9-64.5)	2.2 (0.8-7.1)
Mean ANZROD (SD)	10.9 (18.5)	41.4 (27.8)	7.3 (12.8)
Median APACHE III score (IQR)	49.0 (35.0-68.0)	87.0 (69.0-105.0)	46.0 (33.0-62.0)
Mean APACHE III score (SD)	53.2 (25.2)	87.6 (24.9)	49.0 (21.9)
Median APACHE III ROD (IQR)	6.3 (2.2-20.0)	47.7 (22.4-69.2)	5.1 (1.9-14.1)
Mean APACHE III ROD (SD)	15.6 (20.6)	46.9 (26.8)	11.9 (16.0)
Median TRISS (IQR)	6.1 (0.8-1.0)	29.5 (7.7-63.3)	5.0 (1.0-12.5)
Mean TRISS (SD)	15.0 (21.0)	38.0 (31.4)	11.8 (17.1)
Mean ISS (SD)	23.4 (12.3)	28.3 (14.9)	22.8 (11.8)
Mean NISS (SD)	30.7 (16.2)	42.1 (21.0)	29.3 (15.0)
Mean RTS (SD)	7.0 (1.3)	5.9 (1.8)	7.1 (1.1)
Tertiary (%)	4767 (91.0)	511 (91.1)	4256 (91.0)
Metropolitan (%)	261 (5.0)	30 (5.4)	231 (4.9)
Rural (%)	208 (4.0)	20 (3.6)	188 (4.0)
Private (%)	1 (0.0)	0 (0.0)	1 (0.0)

GCS: Glasgow Coma Scale; ANZROD: Australia and New Zealand Risk of Death; APACHE: Acute Physiology and Chronic Health Evaluation; TRISS: Trauma and Injury Severity Score (estimates of survival); ISS: Injury Severity Score; NISS: New Injury Severity Score; RTS: Revised Trauma Score; SD: Standard Deviation; IQR: Interquartile Range.
*with the exception of gender (p=0.2), ICU length of stay (p=0.7) and hospital type (p=0.1) all other differences are statistically significant (p<0.001).

(26.7) in 2008 to 51.8 (27.0) in 2017. The proportion of patients with at least one chronic medical condition also increased from 4.8% in 2008 to 7.1% in 2017. The majority of patients were male (74.4%) and 3,554 patients (67.9%) received mechanical ventilation. The median ICU length of stay was 4 days (IQR 2-9) and 561 patients (10.7%) died in hospital (Table 1). The main trauma mechanism involved motor vehicle crashes (33.5%), followed by low-velocity falls (13.1%).

Overall discrimination of each scoring system

Table 2 and Fig. 1 outline the overall performance metrics of the six scoring systems. Overall, ANZROD had the best discriminatory performance in predicting in-hospital mortality in ICU patients admitted with a trauma diagnosis (AUROC 0.91; 95% CI 0.90-0.92). The performance of the APACHE III score (AUROC 0.88; 95% CI 0.87-0.90) and APACHE III ROD (AUROC 0.88; 95% CI 0.87-0.90) were lower than ANZROD. The overall difference in AUROC between ANZROD and APACHE III ROD was 0.03 (95% CI 0.02-0.03; p <0.001). TRISS had acceptable performance overall, with an AUROC of 0.78 (95% CI 0.76-0.80). ISS 0.61 (95% CI 0.59-0.64), NISS 0.68 (95% CI 0.65-0.70) and RTS 0.69 (95% CI 0.67-0.72) performed poorly overall.

Overall calibration of each scoring system

The expected overall mortality rate using ANZROD (10.9%) was close to the observed overall mortality rate of 10.7%, with an SMR of 0.98 (95% CI 0.90-1.07). The APACHE III ROD (expected mortality 15.6%; SMR 0.69; 95% CI 0.63-0.75) and TRISS (expected mortality 15.0%; SMR 0.71; 95% CI 0.66-0.77) overestimated overall hospital mortality rates in ICU trauma patients (Table 2). The ANZROD and APACHE III ROD both had low Briers scores of 0.07, compared with a Briers score of 0.09 for TRISS (Table 2).

Scoring systems in older adult (65 years and older) subgroup

Among study patients, 1,295 (24.7%) were older adults, of whom 303 (23.4%) died in hospital. The most common trauma mechanism in older adults was a low-velocity fall (33.0%). Each scoring system had poor discriminatory performance in the older adult subgroup when compared with younger patients, patients admitted to a trauma centre and patients who had sustained a head injury (Table 2 and Fig. 2). The ANZROD had the best predictive value for hospital mortality in older adult ICU trauma patients (AUROC 0.83; 95% CI 0.80-0.85). TRISS, ISS, NISS and RTS all performed poorly in the older adult subgroup (Table 2 and Fig. 2).

The expected mortality predicted by APACHE III ROD for the older adult subgroup was close to the observed mortality (SMR 1.10; 95% CI 0.98-1.23).

Scoring systems in patients under 40 years of age

In total, 2,139 patients were between 18 and 39 years of age. Mortality in younger adult trauma patients (4.6%) was significantly lower than that observed in older trauma patients, despite more severe anatomical injuries (ISS 25.0 vs. 21.1; p<0.001). The most common trauma mechanism in this subgroup were motor vehicle accidents (44.0%). With the exception of ISS, all scoring systems had excellent discrimination in younger adult ICU trauma patients, with an AUROC for ANZROD of 0.93 (95% CI 0.91-0.95; Table 2 and Fig. 2). The predicted mortality for ANZROD was less closely aligned with the observed mortality in younger adults than in the other subgroups (Table 2).

Scoring systems in major trauma centre subgroup

4,546 patients (86.8%) were admitted to a designated Victorian major trauma centre. The hospital mortality rate was lower in patients admitted to a major trauma centre, when compared with non-trauma centres (10.4% vs. 13.0%; p < 0.001). ANZROD, APACHE

Table 2
Area under Receiver operating characteristic curves, Standardised mortality ratios and tests of calibration (Hosmer-Lemeshow C statistics and Brier scores) for each scoring system within each patient group.

Scoring System	Area Under the Receiver Operating Characteristic Curve	Standardised mortality ratio (95%CI)	Hosmer Lemeshow C Statistic	Brier Score*
All patients (n= 5237, mortality 10.7%)				
ANZROD	0.91 (0.90-0.92)	0.98 (0.90-1.07)	161.3	0.07
APACHE III Risk of death	0.88 (0.87-0.90)	0.69 (0.63-0.75)	25.71	0.07
APACHE III Score	0.88 (0.87-0.89)	N/A	-	-
TRISS	0.78 (0.76-0.80)	0.71 (0.66-0.77)	63.8	0.09
ISS	0.61 (0.59-0.64)	N/A	-	-
NISS	0.68 (0.65-0.70)	N/A	-	-
RTS	0.69 (0.67-0.72)	N/A	-	-
Aged 65 and over (n=1295, mortality 23.4%)				
ANZROD	0.83 (0.80-0.85)	1.10 (0.98-1.23)	26.6	0.13
APACHE III Risk of death	0.80 (0.77-0.82)	0.95 (0.84-1.06)	15.7	0.14
APACHE III Score	0.79 (0.76-0.81)	N/A	-	-
TRISS	0.64 (0.60-0.69)	1.30 (1.16-1.45)	43.1	0.17
ISS	0.58 (0.54-0.62)	N/A	-	-
NISS	0.62 (0.58-0.66)	N/A	-	-
RTS	0.67 (0.63-0.70)	N/A	-	-
Aged under 40 (n=2139, mortality 4.6%)				
ANZROD	0.93 (0.91-0.95)	0.75 (0.61-0.90)	52.9	0.04
APACHE III Risk of death	0.92 (0.89-0.94)	0.39 (0.32-0.47)	19.1	0.05
APACHE III Score	0.91 (0.88-0.93)	N/A	-	-
TRISS	0.88 (0.85-0.91)	0.36(0.29-0.43)	26.4	0.06
ISS	0.75 (0.70-0.79)	N/A	-	-
NISS	0.85 (0.80-0.89)	N/A	-	-
RTS	0.87 (0.84-0.91)	N/A	-	-
Major Trauma Centre (n=4546, mortality 10.4%)				
ANZROD	0.91 (0.90-0.92)	0.95 (0.86-1.05)	147.8	0.06
APACHE III Risk of death	0.88 (0.87-0.90)	0.67 (0.61-0.74)	79.7	0.07
APACHE III Score	0.88 (0.87-0.89)	N/A	-	-
TRISS	0.81 (0.79-0.83)	0.73 (0.66-0.81)	71.6	0.09
ISS	0.65 (0.62-0.67)	N/A	-	-
NISS	0.73 (0.70-0.76)	N/A	-	-
RTS	0.71 (0.69-0.74)	N/A	-	-
Traumatic Brain Injury (n=2349, mortality 16.3%)				
ANZROD	0.88 (0.87-0.90)	0.95 (0.86-1.05)	82.4	0.09
APACHE III Risk of death	0.85 (0.84-0.87)	0.67 (0.61-0.74)	23.0	0.11
APACHE III Score	0.85 (0.83-0.87)	N/A	-	-
TRISS	0.79 (0.76-0.81)	0.73 (0.66-0.81)	35.6	0.13
ISS	0.63 (0.60-0.66)	N/A	-	-
NISS	0.74 (0.71-0.76)	N/A	-	-
RTS	0.69 (0.66-0.72)	N/A	-	-

N/A: not applicable; ANZROD: Australia and New Zealand Risk of Death; APACHE: Acute Physiology and Chronic Health Evaluation; TRISS: Trauma and Injury Severity Score; ISS: Injury Severity Score; NISS: New Injury Severity Score; RTS: Revised Trauma Score.
*Briers score only estimated for APACHE III Risk of death, not APACHE III score.

III ROD and APACHE III performed best in predicting hospital mortality (AUROC 0.91 (95% CI 0.90-0.92), 0.88 (95% CI 0.87-0.90) and 0.88 (95% CI 0.87-0.89) respectively). All trauma scores showed better discrimination in the major trauma centre subgroup when compared with the older adult and head injury subgroups (Table 2 and Fig. 3). The SMR for ANZROD, APACHE III and TRISS were similar in the major trauma subgroup to that observed in overall ICU patients (Table 2).

Scoring systems in traumatic brain injury subgroup

In total, 2,349 patients (44.9%) had a diagnosis of traumatic brain injury. 383 patients (16.3%) with head injury died in hospital. ANZROD showed the best predictive value for hospital mortality (AUROC 0.88; 95% CI 0.87-0.90). APACHE III ROD and APACHE III both demonstrated excellent discrimination (AUROC 0.85 (95% CI 0.83-0.87)) (Table 2 and Fig. 5 TRISS had acceptable discrimination (AUROC of 0.79 (95% CI 0.76-0.81)) and NISS 0.74 (95% CI 0.71-0.76), with ISS and RTS performing poorly (0.63 (95% CI 0.60-0.66) and 0.69 (95% CI 0.66-0.72) respectively). The SMR for ANZROD, APACHE III and TRISS were similar in the head injury subgroup to that observed in overall ICU patients (Table 2 and Fig. 5).

Discussion

In this study of 5,237 trauma patients admitted to 25 ICUs between January 2011 and December 2017 and who remained in ICU for at least 24 hours, intensive care-based scoring systems (ANZROD, APACHE III ROD and APACHE III) demonstrated excellent discrimination in predicting in-hospital mortality in ICU trauma patients, when compared with specific trauma scores (TRISS, ISS, NISS and RTS). This was consistent across the four subgroups of

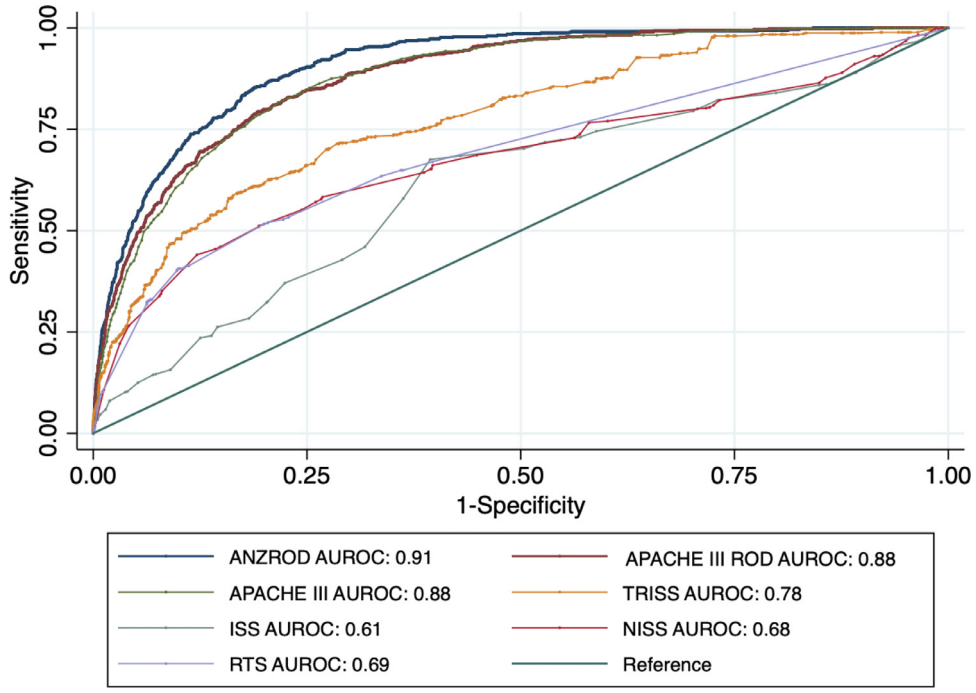

Fig. 1. Receiver operating characteristic curves for in-hospital mortality in ICU patients admitted with a trauma diagnosis.

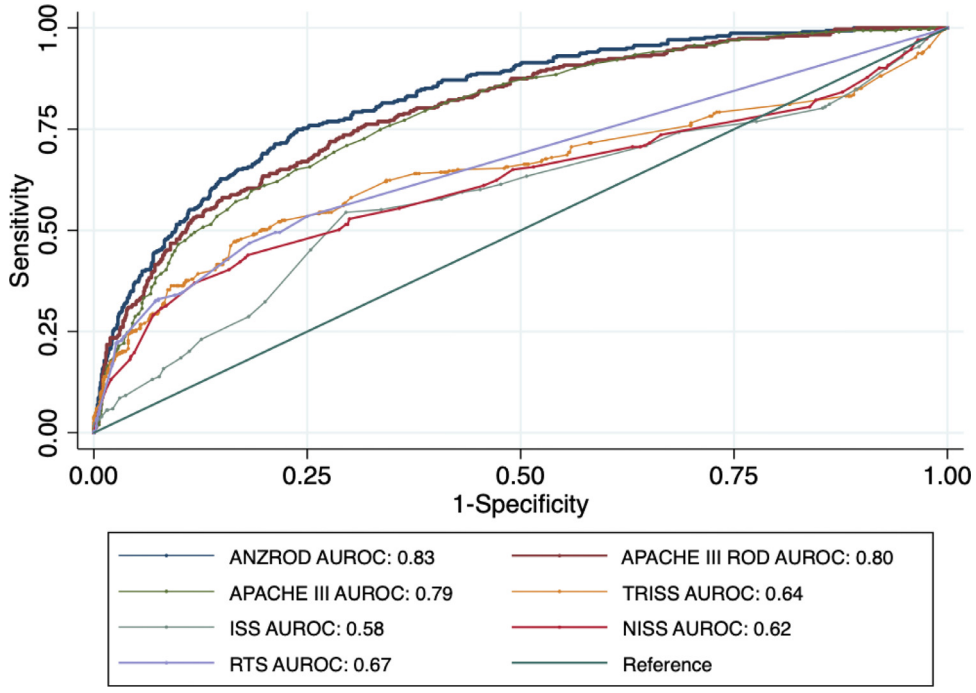

Fig. 2. Receiver operating characteristic curves for in-hospital mortality in ICU patients aged 65 years of age and over.

older and younger adults, major trauma centre and head injury. All scoring systems performed very well in the younger adult subgroup and poorest in older adults. The predicted mortality using ANZROD was close to the observed mortality overall and in younger adults, major trauma centre and head injury subgroups. Calibration was superior in ANZROD and APACHE III ROD when compared with traditional trauma scoring systems, with a lower Brier score than observed for TRISS, ISS, NISS and RTS. The superior performance of ANZROD and APACHE III can be explained by these scores collecting a greater amount of patient information. These scores also collect data closer to the outcome of in-hospital mortality, being assessed at the 24-hour mark of ICU admission. TRISS, ISS, NISS and RTS are all recorded prior to ICU admission and at the time of injury. The lower in-hospital mortality that we observed in ICU patients admitted to major trauma centres when compared with non-trauma centres is of uncertain clinical significance.

Relationship with previous studies

There are a limited number of studies assessing the predictive value of scoring systems in the ICU trauma population. Llompart-

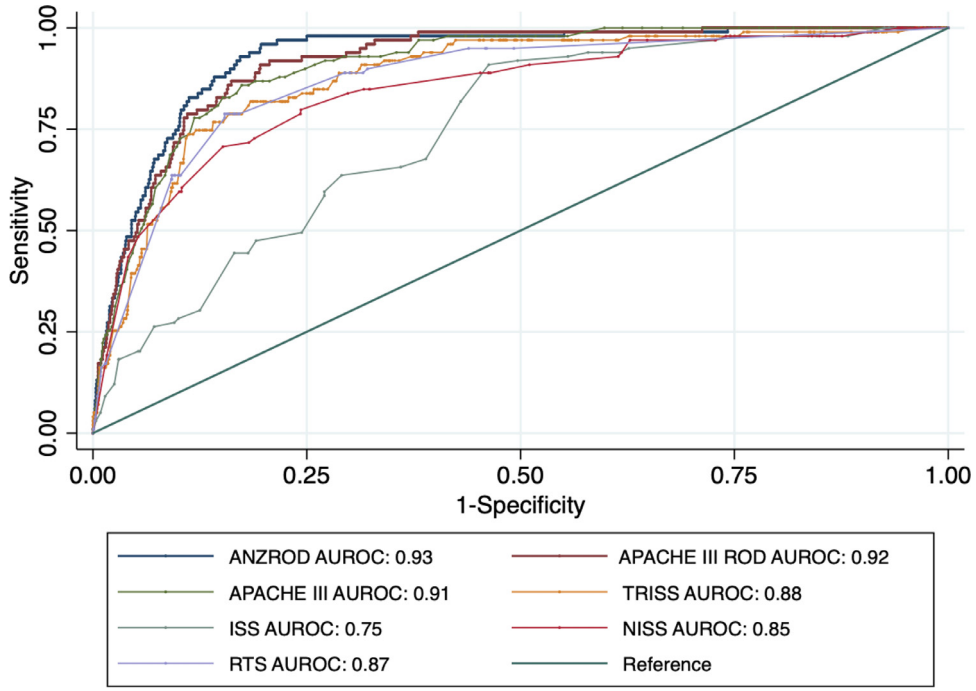

Fig. 3. Receiver operating characteristic curves for in-hospital mortality in ICU patients between 18 and 40 years of age.

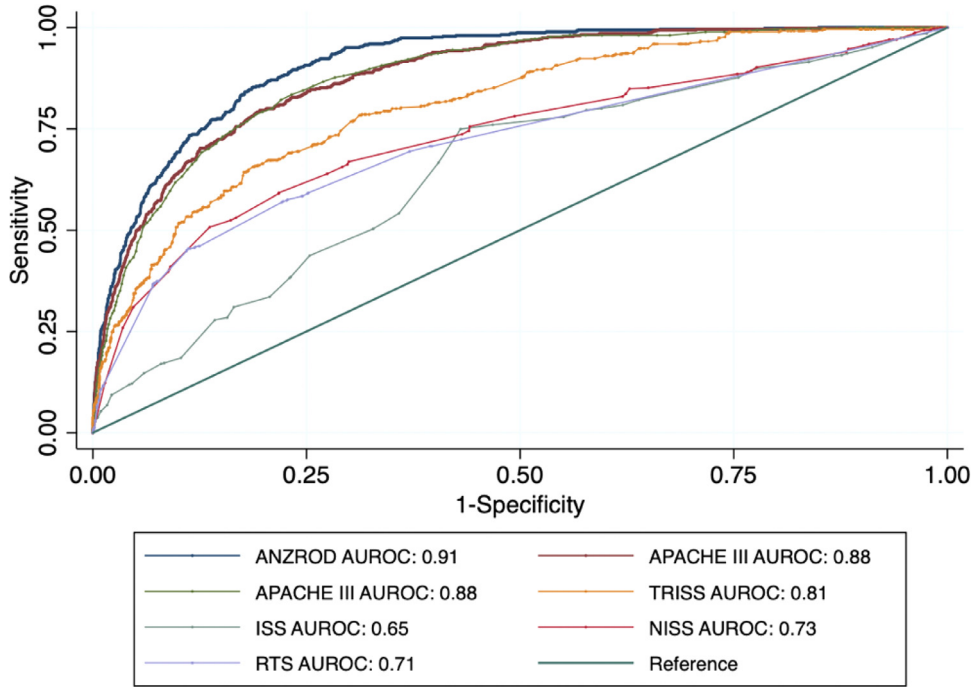

Fig. 4. Receiver operating characteristic curves for in-hospital mortality in ICU patients admitted to a major trauma centre.

Pou and colleagues evaluated the predictive ability of TRISS, GAP, MGAP and T-RTS in a single trauma centre in Spain [23]. They found TRISS to have a higher predictive value for hospital mortality than observed in our study, with an AUROC of 0.90 (95% CI 0.88-0.92). A large number of patients, however, were excluded from the final analysis in this study, the patient cohort was younger, with a higher mortality (17.7%) and the external validity of such a single centre study remains unclear.

Using a German trauma patient dataset from 1993 to 2000, Lefering et al described a higher AUROC for TRISS, RTS and ISS than was observed in our study. However, overall mortality was high at 16.6% [24]. Of the traditional trauma scores analysed, TRISS performed best in predicting hospital mortality, with an AUROC of 0.85. The much younger cohort of the study population in this German cohort, and the higher mortality rate, may partially explain some of the observed differences in scoring system performance when compared with our findings. Additionally, our dataset was limited to ICU patients who had survived for greater than 24 hours, compared with all hospital admissions in this study. As we observed, the pattern of injuries in younger patients is in general more extensive than the injury distribution found in older patients. Consistent with our findings, in a German cohort of around 45,000

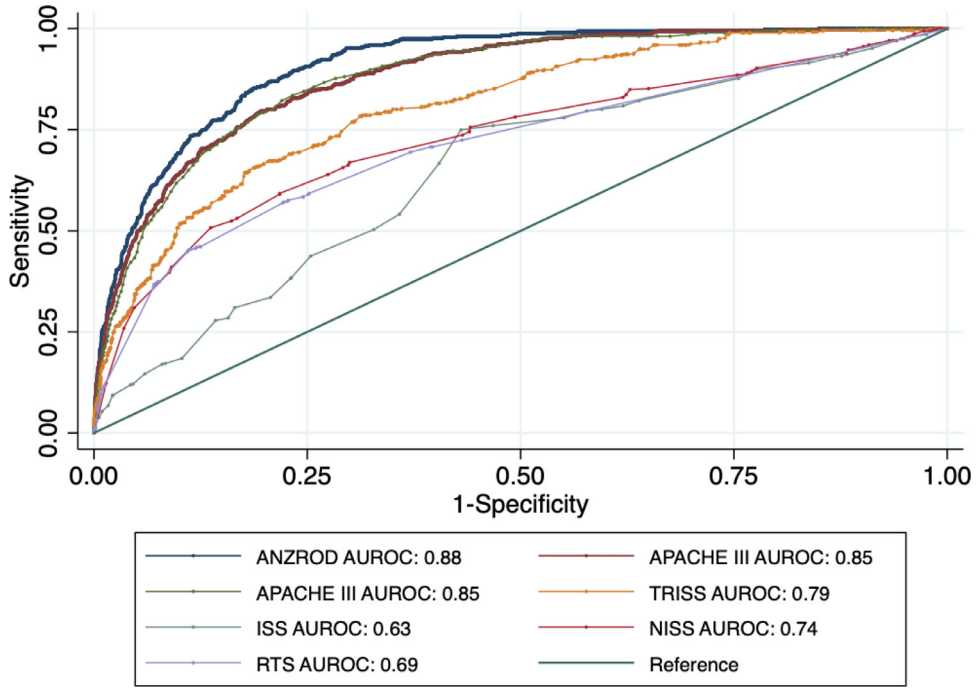

Fig. 5. Receiver operating characteristic curves for in-hospital mortality in ICU patients with traumatic brain injury.

patients not restricted to ICU, Paffrath and colleagues found that an anatomical definition of major trauma was insufficient in predicting hospital mortality. Trauma patients who had an ISS of $\geq$ 16 and no physiologic compromise had a mortality rate of 3.1%. This compared with a mortality rate of 86% when five physiological risk factors were present [20].

In a meta-analysis performed in 2016, Deng et al compared the performance of ISS and NISS using data from 11 studies. Overall, the AUROC of both scores was reported as 0.9, much higher than we observed in our study [25]. However, the sample size was below 1,000 in all but two of these studies. Only one study in this meta-analysis had a comparable dataset to our study and the mortality in this patient cohort was only 3.8% [26].

Strengths of the study

This is one of the largest database studies to assess the discrimination and calibration of trauma scoring systems in the Intensive Care setting. In addition, this is the first study to assess the performance of ANZROD in comparison to other more traditional trauma scores in predicting the outcome of trauma patients admitted to ICU. The size of the dataset increased generalisability, at least within the Australian setting. The separate analysis by subgroup (age, major trauma centre and head injured patients) allowed the discrimination of each scoring system to be analysed across four subsets of the ICU trauma population.

Limitations of the study

Our study was limited to patients from the state of Victoria, Australia. As such, generalisability is limited to the Australian setting. Due to the complex nature of the ANZROD score, it cannot routinely be applied at the bedside and thus, cannot influence individual patient management decisions. Moreover, ANZROD has only been prospectively validated in the ICU population of Australia and New Zealand. The performance of the anatomical scoring systems was not assessed outside of the ICU population in this study, and no conclusions can therefore be made about the respective performance of these scores in the non-ICU population.

We have not compared ANZROD against specific head injury severity scores, as our dataset did not allow us to calculate these. However, the performance of ANZROD was excellent in all of the categories we considered and therefore has the advantage that it can applied to all trauma admissions to critical care. In addition, a comparison with newer trauma scoring systems, such as MGAP and GAP, was not possible within the VSTR dataset.

There was a significant mortality difference between patients who were included in the final analysis and those who were excluded due to inability to link some patients between ANZICS-APD cases with the VSTR. Selection bias cannot be excluded from the final analysis.

The traditional trauma scores (TRISS, ISS, NISS and RTS) refer to the severity of injury on admission to hospital, whereas the ICU-specific scores (ANZROD and APACHE III) relate to injury severity within the first 24 hours of ICU admission. All trauma scores will be influenced by the pre-hospital care administered but ANZROD and APACHE III will additionally be affected by treatment provided prior to and during the first 24 hours of ICU admission. It is unknown how the performance of ANZROD or APACHE III would have performed if measured at hospital admission. The impact of unmatched patients and patients who died after admission to hospital but prior to ICU admission on our findings is unknown.

Study Impact

This is the first study to specifically investigate the performance of the ANZROD score in predicting hospital mortality in ICU patients admitted with a diagnosis of major trauma and who remained in ICU for at least 24hours. The superior ability of the ANZROD score in predicting mortality means that it should be the scoring system used to determine illness severity in future research studies involving ICU trauma patients in Australia. The performance of TRISS in predicting hospital mortality in trauma patients within the Australian ICU setting was lower than observed in previous studies. ISS and RTS are neither specific nor sensi-

tive when evaluated on patients who have survived to 24 hours on ICU, however they may still have some utility when applied to the wider hospital population. Our results highlight that all trauma scoring systems had lower discrimination within the older adult subgroup of trauma patients in ICU. This likely reflects the different trauma mechanisms observed in older adult patients, with older ICU trauma victims likely to be injured as a result of a fall from standing or from a ladder. In general, these patients have less severe anatomical injuries than younger trauma patients, but they are much more likely to die in hospital. It is well recognised that this is a rapidly expanding population, and more research is needed to more accurately predict in-hospital mortality in this patient subgroup.

Conclusion

ANZROD and APACHE III had a superior performance when compared with traditional trauma-specific scoring systems in determining in-hospital mortality in ICU patients admitted with a trauma diagnosis and who remained in ICU for at least 24 hours. This was observed both overall and in each of the subgroup analyses, with all scoring systems performing best in younger patients. These findings imply that trauma research in Australia can rely on ICU specific scoring system both for baseline risk adjustment and stratification of randomisation.

Declaration of Competing Interest

I declare that there is no conflict interest from any of the authors in this study.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.injury.2021.03.049.

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