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ORIGINAL RESEARCH

Determining the most effective level of TRISS-derived probability of survival for use as an audit filter

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Abstract

Objective: To determine the most effective cut-off of TRISS-derived probability of survival (TRISS-PS) for the selection of trauma deaths for audit, using a large sample of trauma deaths from the United Kingdom (UK).

Methods: TRISS-PS and avoidability of death (as judged by an independent peer review panel) were compared for a sample of 222 trauma deaths. Sensitivity, specificity and predictive values were calculated for the 0.5 screening cut-off. ROC curves were derived to assess the ability of different levels of TRISS-PS to identify avoidable deaths. Calculations were made for both the raw sample and the sample adjusted for the sampling method used.

Results: For the weight-adjusted sample, the sensitivity of TRISS-PS greater than 0.5 for the detection of avoidable death is 80% (95% CI 61–91%), the specificity is 86% (95% CI 80–90%), PPV 42% (95% CI 29–56%) and NPV 97% (95% CI 93–99%). Twenty percent of avoidable deaths would have been 'missed' if the 0.5 level of audit filter had been used. Based on the same sample, the best cut-off is at TRISS-PS 0.33, with a sensitivity of 90% and specificity of 80%. It is estimated that this cut-off would have selected 62 deaths for audit and failed to identify 2 out of 25 avoidable deaths.

Conclusion: The previously accepted audit filter of TRISS-PS of greater than 0.5 fails to identify a significant proportion of avoidable deaths. This study suggests that the most effective level of audit filter cut-off of TRISS-PS for the trauma system studied is 0.33. This level would identify 90% of avoidable deaths with 80% specificity. Similar ROC curve analysis could be used to determine appropriate TRISS-PS cut-offs for institutions or other trauma systems.

Key words: *audit, preventable death, trauma, TRISS.*

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Introduction

The evaluation of outcome and the identification of opportunities for improved performance are key components of a health care system. By their nature, some of these components will be objective and some subjective. For victims of major trauma, the widely accepted objective outcome evaluation uses the TRISS methodology.[1] Using this method, the probability of survival for a particular patient can be calculated by relating the degree of physiological compromise as measured by the Revised Trauma Score[2] to the spectrum of anatomical injury as quantified by the Injury Severity Score (ISS)[3] and factoring in mechanism of injury and patient age as additional variables. This methodology has been used both for comparisons of the performance of a hospital or trauma system with others and for the detection of patients with unexpected outcomes. The latter can be subjected to an audit process in an attempt to identify opportunities for improved performance.

Traditionally the level of TRISS-predicted probability of survival (TRISS-PS) used as an audit filter to identify preventable deaths has been 0.5. In other words, the records of patients with a probability of survival greater than 50% who die are audited (usually by peer review) to determine if the death was avoidable and whether there are aspects of care that can be changed in an attempt to avoid this outcome in the future. It appears that the original choice of the 0.5 level was arbitrary. It has been confirmed as having high sensitivity and negative predictive value by Hill *et al.*[4] That study, however, had a small sample with very few patients with TRISS-PS less than 0.5. Other studies from Australia have questioned this.[5–7]

This study, using a large sample of trauma deaths from the UK, aims to determine an effective cut-off of TRISS-PS for the selection of trauma deaths for audit.

Methods

This study is a subgroup analysis of deaths from trauma analysed as part of the assessment of the cost-effectiveness of a regionalized trauma service.[8,9] That study, conducted between 1990 and 1993, subjected a stratified sample of trauma deaths from the North-west Midlands, Lancashire and Humberside regions of the UK to independent, blinded peer review for avoidable death.

For the purposes of the study, avoidable death was defined as 'one in which the cause of death could have been prevented and the outcome reversed if the patient had been managed (within the present state of clinical knowledge) with all the necessary skills and resources appropriate to the severity of injury.' No numerical or other qualifiers were specified.

In sample selection for the parent study, emphasis had been placed on deaths that were unexpected or in patient groups that might have been directly affected by introducing a trauma system. A stratified sample was used comprising all deaths from injuries with an ISS less than or equal to 16 in patients aged under 75 years, a random sample of approximately 50% of deaths following interhospital transfer, any deaths in a patient taken directly to the trauma centre in which that hospital was not the geographically nearest emergency centre and a random sample of all other trauma deaths. Deaths in patients with isolated fractured neck of femur were excluded. The total sample comprised 415 patients. As this study is focusing on victims of major trauma, additional entry criteria for this substudy were ISS greater than or equal to 16 and availability of data for calculation of TRISS-derived probability of survival using the UK coefficients (Yates, pers. comm.).

The expert review panel comprised five specialists, one each from the fields of emergency medicine, neurosurgery, general surgery, orthopaedics and anaesthesia. All deaths were reviewed by each expert independently. Data considered included pre-hospital, hospital and post mortem data. Deaths were classified as 'potentially avoidable' if four out of five experts agreed. Equivocal cases were assessed at periodic meetings attended by all reviewers and an independent chairman and classified by consensus. Unfortunately, the emergency medicine specialist had to leave the panel half way through the study. Rather than introduce potential bias by the addition of a new panel member, it was decided to proceed with the remaining members. Agreement for classification as 'potentially avoidable' was adjusted to four out of four. Tests of interrater and intrapanel reliability were conducted with high reproducibility. A detailed account of the peer review methodology is available.[8]

Data were analysed both for the raw sample and for the reweighted sample. Reweighting of the sample was important because the study sample included different proportions of patients in each entry criteria group (i.e. 100% deaths in patients taken to the trauma centre who bypassed a potentially suitable

Table 1. Potentially avoidable deaths with TRISS-PS (UK) less than 0.5

Sex	Age	ISS	UKPS	Mechanism of injury	Main reason for avoidability	Transfer
Female	57	25	0.46	Fall	Poor airway management, delay to neurosurgical care	Yes
Male	64	38	0.37	Fall from window	Delayed surgery, poor resuscitation	Yes
Male	62	38	0.37	Pedestrian	Delayed diagnosis of intra-abdominal bleeding	No
Male	34	21	0.35	Stabbing	Delayed surgery for torso stab wounds	No
Female	53	35	0.33	Pedestrian	Access to neurosurgery. Delay to craniotomy more than 4 h	Yes
Male	75	25	0.18	Fall	Time to craniotomy more than 4 h, delay to intubation	Yes
Male	73	42	0.06	Fall	Time to craniotomy more than 3 h, poor airway control	No
Male	67	30	0.03	Fall	Delay to intubation, delay to neurosurgical care	Yes

TRISS-derived probability of survival calculated with UK coefficients; ISS, injury severity score.

hospital, approximately 50% of deaths in patients who died following transfer between hospital and a smaller proportion of other trauma deaths). Reweighting gives an estimate for the true case mix of, if all deaths from major trauma had been assessed. It was performed by weighting the sample by the inverse of the sampling fractions. Descriptive analyses and 95% confidence intervals for the TRISS-PS level of 0.5 were calculated for both the raw and weight-adjusted samples. Receiver operator characteristic (ROC) curves were made for both samples to assess the ability of various cut-off levels of TRISS-derived probability of survival to discriminate between avoidable and non-avoidable trauma deaths.

Ethical approval for the study was obtained from all of the participating hospitals.

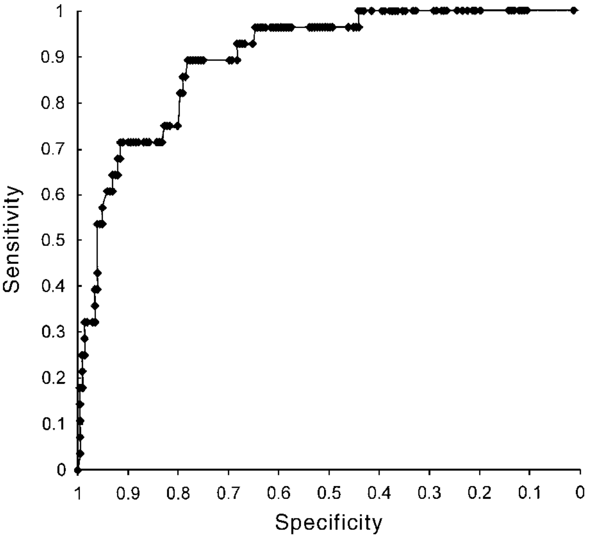

Figure 1. Ability of TRISS-derived probability of survival to discriminate between avoidable and non-avoidable death based on raw data.

Results

Two hundred and twenty-two patients had an ISS greater than or equal to 16 and data available for the calculation of TRISS-PS. Two hundred and sixteen (97%) trauma deaths were due to blunt trauma.

Forty-seven trauma deaths had a TRISS-PS greater than 0.5. Twenty-eight trauma deaths were judged by the expert review panel to be potentially avoidable, but only 20 of these were identified by TRISS-PS of greater than 0.5. Therefore, for the raw sample, the sensitivity of a TRISS-PS of 0.5 for identifying avoidable death was 71% (95% CI 51–87%), specificity 86% (95% CI 80–91%), PPV 43% (95% CI 28–58%) and NPV 95% (95% CI 91–98%). For the weight-adjusted sample, the sensitivity of TRISS-PS greater than 0.5 for avoidable death is 80% (95% CI 61–91%), specificity 86% (95% CI 80–90%), PPV 42% (95% CI 29–56%) and NPV 97% (95% CI 93–99%). Twenty percent of avoidable deaths would have been 'missed' if the 0.5 level of audit filter had been used (95% CI 9–39%).

The eight potentially avoidable deaths not identified by TRISS-PS greater than 0.5 are summarized in Table 1. Of note, the majority of these trauma deaths were transferred from the initial receiving hospital for definitive care. In particular, delays to specialist neurosurgical care are prominent. Pre-hospital issues were not judged to be major contributors to these deaths.

The ROC curve for the raw sample is shown in Fig. 1. The area under the curve is 0.896 with a standard error of 0.028. The best cut-off point, as suggested by this graph, is at TRISS-derived probability of survival 0.22. This had sensitivity of

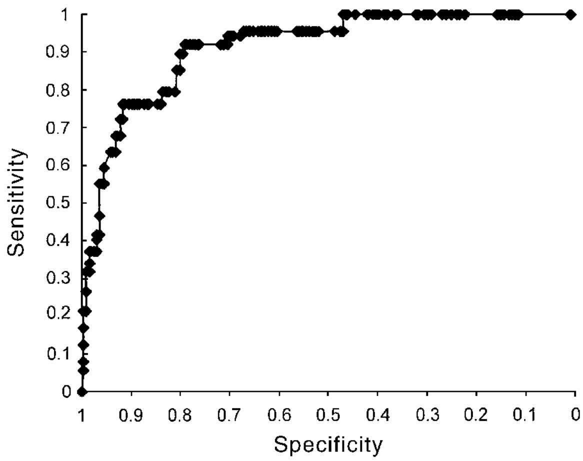

Figure 2. Ability of TRISS-derived probability of survival to discriminate between avoidable and non-avoidable death based on weight-adjusted data.

89% and specificity of 70%. It would have selected 85 trauma deaths for audit and would have failed to identify only three out of 28 avoidable deaths.

The ROC curve for the sample-weight-adjusted data is shown in Fig. 2. The area under the curve is 0.914 with a standard error of 0.027. It should be noted that for the weight-adjusted sample, the estimated number of avoidable deaths was 25 (compared to 28 in the raw sample). The best cut-off point, as suggested by this graph, is at TRISS-derived probability of survival 0.33. This had sensitivity of 90% and specificity of 80%. It is estimated that this cut-off would have selected 62 trauma deaths for audit and have failed to identify two avoidable deaths.

The performance of the cut-off levels , 0.33, 0.4 and 0.5 for both raw and weight-adjusted data is summarized in Table 2.

Translated into practical terms, based on the weight-adjusted data, at the TRISS-derived probability of survival 0.33 cut-off, 62 trauma deaths would be chosen for audit. Avoidable death would be found in 23 (37%) and only two (8%) avoidable deaths would be missed. At TRISS-derived probability of survival 0.4 cut-off, 55 trauma deaths would be audited, 20 of the avoidable deaths would be identified but five would be missed. Similarly, at TRISS-derived probability of survival 0.5, 48 trauma deaths would be audited and 20 of the avoidable deaths would be identified but five would be missed.

Table 2. Comparison of predictive ability of TRISS-derived probability of survival for avoidable death for various TRISS-derived probability of survival cut-off levels

	Raw sample	Weight-adjusted sample	Number of cases requiring audit
Total trauma deaths	222	222	
Avoidable deaths	28	25 (estimated)	
Cut-off 0.33			
Sensitivity	86%	90%	62
Specificity	78%	80%	
True positive	24	23	
False positive	43	39	
False negative	4	2	
Cut-off 0.4			
Sensitivity	75%	80%	55
Specificity	81%	82%	
True positive	21	20	
False positive	36	35	
False negative	7	5	
Cut-off 0.5			
Sensitivity	71%	76%	48
Specificity	86%	87%	
True positive	20	20	
False positive	27	28	
False negative	8	5	

Discussion

The TRISS methodology[1] uses a mathematical model to predict outcome following trauma. Therefore, it has range of sensitivities and specificities for detection of avoidable death based on the audit cut-off point chosen. Conventionally, the audit filter cut-off used is TRISS-PS of 0.5; that is, trauma deaths with a TRISS-PS of greater than 0.5 are subjected to audit. Although intuitive, the evidentiary basis for the choice of this level is unclear. It is possible that another level of TRISS-PS is more effective as an audit filter, giving better sensitivity and specificity. Additionally, it is possible that a different level is more appropriate to trauma systems than that chosen for individual institutions.

The 0.5 cut-off was originally validated by Hill in a small study of 24 trauma deaths.[4] That study found TRISS-PS of more than 0.5 to be 100% sensitive and 42% specific in identifying potentially avoidable trauma death with a positive predictive value (PPV) of 31% and a negative predictive value (NPV) of 100%. In another small study of 38 trauma deaths from Liverpool Hospital in Sydney, Sugrue *et al.* challenged the validity of the TRISS-PS 0.5 filter, finding that it had a sensitivity of 67%, specificity of 63%, PPV of 25% and NPV of 91%.[7] McDermott *et al.* evaluating 73 road deaths in Victoria, also raised doubts about the TRISS-PS 0.5 audit filter cut-off, finding it had a sensitivity of 69%, specificity of 41%, PPV of 48% and NPV of 63%.[6] It should be noted, however, that the methodology used in the latter study has a bias towards finding TRISS-PS 0.5 inadequate as it directed the peer review panel to classify a death as preventable if the probability of survival was more than 25%. Thus one tool (TRISS) was using a probability of survival cut-off of 50% and the peer review panel a level of 25%, so disagreement between the two was predictable.

The current study found that a cut-off of TRISS-PS of 0.5 performed suboptimally, failing to identify about 20% of avoidable deaths. ROC curve analysis of data (adjusted for the sampling method) suggests a more effective cut-off for the trauma system studied is 0.33. It suggests that the 0.5 cut-off may miss a significant number of avoidable deaths and therefore, that potential opportunities for improvement in care are being missed. An alternative explanation for this finding is that clinicians (in this case the expert panel) are over-optimistic with respect to the survivability of injury. The truth may well be a combination of both. A well designed audit process may assist clinicians to be more realistic in their assessments.

There are some important differences between the current study and the previous studies. The current study has a much larger sample size than previous studies (222 deaths vs. 24 deaths,[4] 38 deaths[7] and 73 deaths[6]) and a higher proportion of TRISS-PS less than 0.5 in trauma deaths subjected to expert review (79% vs. 30%,[4] 47%[7] and 55%[6]). This is in part explained by the sampling methodology used in this study that aimed to detect potentially avoidable death and has resulted in the evaluation of a much larger group of more severely injured patients. Additionally, Hill[4] and Sugrue's[7] samples are derived from single hospitals that have all specialty services on-site and are predominantly metropolitan samples with the study hospitals being the first hospital of attendance for the majority of patients. McDermott's study is limited to victims of road trauma.[6] The current study is based on geographical areas and their related health systems rather than a single hospital and includes all types of trauma. Thus it is more likely to highlight problems with regionalized specialty services, initial reception at smaller hospitals and the referral and transfer process. This is borne out by the analysis of avoidable deaths 'missed' by TRISS-PS greater than 0.5, which has a high proportion of patients who were transferred for higher level care and of patients requiring specialist neurosurgical care — a regionalized service in the UK.

One other study has attempted to determine the most effective cut-off of TRISS-PS for use as an audit filter using related methodology. Coats *et al.* compared TRISS-predicted outcome with actual outcome in 1603 patients treated at a single centre using ROC methodology.[10] They found the best cut-off point to be at TRISS-PS of 0.76 and suggest this as the appropriate audit filter for their institution. However, the methodology of that study is open to question. It adopted actual outcome as the 'gold standard'. In other words, it determined the level of TRISS-PS that could be used to predict death. Death is not the outcome of interest for the trauma audit process. It is the selection of a subset of deaths for review from which lessons may be learnt that is central to this process. Without an assessment of avoidability of death or error in management it is not possible to set a valid audit filter.

The chosen cut-off point for an audit filter will always be a trade-off between sensitivity (identification of avoidable deaths) and specificity (the number of trauma deaths audited to detect these). The latter is a particularly important practical issue. It is clinicians who perform these audit processes and finding the time to do so competes with other clinical and administrative priorities. Balancing against this is the 'lost' benefit of lessons that could be learnt from avoidable deaths not subjected to audit. The lessons contained in these trauma deaths may be at least as important as those with a higher TRISS-derived probability of survival. Also, as trauma care and survival improves, the number of potential survivors at lower TRISS-PS will grow and an increasing number of improvement possibilities may be hidden below an inappropriate audit filter cutoff. Thus the level of audit filter chosen by an institution or system will reflect both the workload involved in the audit process and the search for improvements in care. That choice should be informed by the predicted performance of each potential cut-off level. This study provides the first detailed analysis in this regard.

There is a strong argument that TRISS-PS is not the ideal tool for the evaluation of trauma outcomes. It has the major limitation of requiring the elements of the RTS to be documented at initial presentation. This data is usually available in only a moderate proportion of trauma cases. In fact, good clinical reasons such as pre-hospital intubation may make its collection impossible. By using TRISS-PS as the audit filter, important lessons from the group in whom it cannot be calculated are lost as these cases are not included in the selection process. The development of another statistical model for outcome prediction based on data that are universally accessible (such as age, ISS and head abbreviated injury score) might be more useful.

This study has some limitations that should be considered when interpreting the results. The study looked specifically at avoidable deaths. It did not look at the issue of unexpected survivors, which may also be a valid subject of study in the evaluation of trauma systems and outcomes. The 'gold standard' (potentially avoidable death) was decided by an expert panel. Although the panel was independent of the study region and blinded to hospital identification, the validity of this methodology has be challenged.[11,12] The potential problems include subjectivity, lack of reproducibility, poor interrater reliability, the role of the benefit of hindsight and lack of external validity. In addition, there was an unavoidable change to panel composition and process during the study that may have influenced case selection. The patient group does not comprise all the trauma deaths in the regions studied. It is a sampled set and the sampling process may have resulted in bias in the results. To a large extent, this concern has been negated by the weight-adjusted analysis. The study looks at one regional area within the UK health system. As the UK trauma system is different from those in the USA and Australasia and the study region may differ from other UK regions, generalizability to other settings may be limited. Generalizability may also be limited by the casemix of the study sample. Only 3% of patients had penetrating trauma, thus limiting generalizability to settings with a higher proportion of penetrating trauma victims.

Conclusion

The previously accepted audit filter of TRISS-PS of greater than 0.5 fails to identify a significant proportion of avoidable deaths and thus opportunities for process or system improvement may be missed. This study suggests that the most effective level of audit filter cut-off of TRISS-derived probability of survival for the trauma system studied is 0.33. This level would identify 90% of avoidable deaths with 80% specificity. Similar ROC curve analysis could be used to determine appropriate TRISS-PS cut-offs for institutions or other trauma systems.

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