Predicting outcome after multiple trauma: which scoring system?

M.N. Chawdaa,1, F. Hildebrandb, H.C. Papeb, P.V. Giannoudisc,*

aHannover, Germany
bUnfallchirurgische Klinik, Medizinische Hochschule, Hannover, Germany
cSt. James University Hospital, Beckett Street, Leeds LS9 7TF, UK

Accepted 8 April 2003

Summary We have undertaken a review of the commonly used scoring systems to identify advantages and possible pitfalls involved in their use. Currently, there is a variety of systems available for scoring trauma severity. Some of them are based on the anatomical description of the injuries, whilst others are based on physiological parameters. The most widely used systems for the purpose of predicting outcome after trauma are based on combined anatomical and physiological parameters. Systems such as the Injury Severity Score (ISS) and the Trauma Injury Severity Score (TRISS) have served some useful purposes and have proved popular over time, but it now seems that there is no ideal scoring system available. The task of incorporating various factors such as pre-existing morbidity, age, immunological differences and different genetic predispositions has made the prospect of creating a universally acceptable and applicable trauma-scoring system extremely arduous, if not impossible. Therefore caution should be exercised when using any of the existing scoring systems until an ideal one becomes available.

© 2003 Elsevier Ltd. All rights reserved.

Introduction

Trauma is an important health problem and a leading cause of death particularly in younger adults and adolescents,96,98 it may be seen as a neglected disease of modern society.40,70 Reported mortality rates for severely injured patients remain substantial, ranging from 7 to 45%.7,91,92

The observed variation in mortality and long-term morbidity between different centres and countries could reflect differences in the quality of management, or different injury severity and/or individual patient characteristics in the study populations. In such instances it is vital that study populations be comparable regarding the prognostic variables used. This aim can be achieved by using an instrument, a scoring system, which considers these variables.4,5,9,18,72,89 However, we should note that the differences could reflect inaccuracies, or errors, inherent in the scoring system used to synthesise or quantify such information.

A satisfactory scoring system is essential to answer such questions as 'how it is that the survival rate of 58% in your trauma centre is actually better than the survival rate of 97% in some other hospital where the patients are much less seriously injured'.97 It is therefore of pivotal importance that a scoring system should measure what it is supposed to measure.
There are certain requirements that a scoring system should fulfil: accuracy, reliability and specificity. If it fulfils these, then the system will serve various useful purposes as follows:

- the ability to predict outcome from trauma (mortality prediction is perhaps the most fundamental use of injury-severity scoring, followed by other outcome measures);
- comparison of therapeutic methods;
- a pre- and inter-hospital triage tool;
- a tool for quality-improvement and prevention programme;
- a tool for trauma research.

A trauma-scoring system converts the severity of injury into a number, so helping clinicians to speak a common language in quality-assurance and quality-control programmes. The plethora of available scoring systems for trauma suggests that there is a need for a universally applicable system, but this goal may be difficult to achieve. Furthermore, to summarise the severity of different injuries in one patient using a single number, is difficult at best, and the task of developing a scoring system that would be able to predict various outcomes in different populations theory becomes more complex.

The purpose of this review article is to consider the existing, most frequently used scoring systems and to assess which system provides the best outcome prediction following trauma.

**Historical perspectives**

The categorisation of injury has been of interest to the military since record keeping began. The ancient Egyptian papyrus of Edwin Smith has a description suggesting a categorisation of injuries into three groups: (i) can be treated effectively; (ii) cannot be treated effectively; (iii) are immediately fatal. Later on, (in the British Medical Journal) Dunbar published 'Homer's record from the Iliad of legendary combatants', showing high mortality in such battles. The characterisation of injury patterns was also attempted in the early 20th century: the French surgeon René Le Fort discovered that the human face fractured mainly in only three ways, despite the variety of modes of injury.

**Evolution of trauma scoring in the modern era**

The modern, systematic evaluation of trauma severity began during the 1950s with De Haven's research on light-plane accidents, which led him to attempt the objective measurement of human injury. Subsequently, interest in automobile crashes prompted a small group of physicians, engineers and researchers to continue the development of an injury-description system, an effort that culminated in the publication of the first Abbreviated Injury Scale (AIS) in 1971. This scale included only 73 main injuries, but did include a consensus-derived severity measure for each injury, varying from 1 (minor) to 6 (fatal). Only blunt injuries were included in this first AIS. The AIS was followed by the development of the Comprehensive Research Injury Scale. The AIS has since been modified six times, the most notable being the 1985 (AIS-85) and 1990 revisions (AIS-90). It is important to remember that no mechanism for summarising multiple injuries into a single score for an individual patient was proposed in the AIS. Baker et al. addressed this particular limitation 3 years later in 1974 with the creation of the Injury Severity Score (ISS). It is noteworthy that the AIS was the basis for the ISS. The ISS has reigned as the standard for injury measurement for many years, with certain challenges and modifications. Champion et al. in 1980 introduced the Anatomic Index (Al), which was based upon the vocabulary of anatomical injury description.

The physiological course after injury is highly dynamic and capable of profoundly influencing the outcome, so the need to incorporate the physiological data into the scoring system was realised and this led to the development of the Trauma Injury Severity Score (TRISS). The most widely used method had its inception in 1981, followed by further consolidation of the concept with the Major Trauma Outcome Study. This method provided improvements in the ability to predict outcome, in particular mortality after trauma, and therefore acquired world-wide popularity despite its later recognised limitations.

To improve outcome predictions further, in 1990 Champion and co-workers on behalf of American College of Surgeon Committee on Trauma proposed A Severity Characterisation Of Trauma (ASCOT), a predictive measure of outcome that incorporates AIS injury descriptions, age, and physiological data into a single score. This method showed some early promise but failed to gain wide-spread acceptance, probably because of the computational complexity involved in deriving the scoring system.

The International Classification of Diseases-based Injury Severity Score (ICISS), ninth edition, proposed by Osler et al. and Rutledge et al. in 1996, addresses the deficiencies of the ISS and attempts to rectify them.
In 1997, Baker, the originator of the ISS, after recognising its shortcomings, together with Osler and Long proposed the New Injury Severity Score (NISS), which has demonstrated some improvements. The NISS score has shown promise in predicting multiorgan failure (MOF) after trauma.

The latest addition to the existing scoring systems, the Harborview Assessment of Risk of Mortality (HARM), was proposed by AlWest et al. in 2000 in a further attempt to modify trauma-outcome prediction. This system is also based on ICD-9CM (International Classification of Disease, Ninth Clinical Modification) codes, making use of available hospital data for this purpose.

### Fundamentals of a trauma-scoring system

The term trauma scoring incorporates two different but related entities: (i) injury description and (ii) trauma scoring; the past 30 years have seen improvements on both these fronts. The ideal scoring system should promise an accurate, reliable and reproducible description of the injuries, which would subsequently be used as a basis for calculating trauma scores.

Injury description requires a large lexicon of different possible injuries: AIS-90 includes more than 1300 different injuries and the ICD-9CM catalogue contains over 2000 injuries. Outcome assessment is incomplete on the basis of injury description (anatomical) only, e.g. injury to the liver may be fatal if associated with severe bleeding and prolonged hypotension, but less lethal if the duration of hypotension is short or it is treated in time. This example clearly demonstrates the fact that anatomical description alone is not enough to help predict the outcome. Therefore, majority opinion suggests that injury description should include both anatomical and physiological descriptions.

Injury severity may also vary with the type of outcome assessment undertaken, e.g. aortic laceration would have a high severity when the outcome criterion is mortality, but it would be low severity if disability were the outcome measure.

Moreover the individual resources or reserves needed to withstand multiple injuries vary between patients, as determined by a variety of factors such as age, pre-existing disease and probably genetic predisposition. Therefore, when planning an outcome assessment on a group of patients one must produce conclusions based on all of these various contributing factors.

A concept expressed by Osler mentioned below, is a useful way of summarising the outcome-prediction algorithm:

\[ \text{outcome} = \text{anatomical injury} + \text{physiological injury} + \text{patient reserve} \]

Statistically speaking this formula translates into a multivariate problem, that requires multiple-regression analysis to predict outcome. With better understanding of statistical concepts such as the receiver—operator curve (ROC) and the Hosmer—Lemeshow (HL) statistic, one can improve understanding of trauma-scoring systems.

### Overview of commonly used trauma-scoring systems

The available scoring systems can be divided in to different categories for the purpose of description, which can be made in different ways as follows:

1. based on criteria used in the scoring systems themselves, e.g. anatomical, physiological and combined anatomical solidus physiological (Table 1);
2. according to their most commonly adopted application (Table 2):
   - (a) scoring of injury severity for outcome prediction, e.g. ISS, NISS, TRISS,
   - (b) scoring of injury distribution, e.g. Glasgow Coma Scale (GCS), TTS, AIS, organ-injury scales,
   - (c) follow a clinical course, e.g. APACHE (see further) on the intensive care unit.

The descriptive classification (1) is the most widely reported in the literature, and therefore for ease of understanding we shall follow the same pattern in this account.

### Physiological scores

#### Revised Trauma Score (RTS)

The RTS, introduced in the early 1980s, is one of the most commonly used physiologic scores. It employs three specific physiological parameters, the GCS, systemic blood pressure (SBP) and the respiratory rate (RR). These parameters are coded from 0 to 4 based on the magnitude of physiological derangement (Table 3).

The RTS is calculated by adding together the coded values for each of these three physiological parameters.

When used for field triage, the unweighted RTS determined by simply combining the coded values
ranges from 0 to 12 and is calculated very easily. A score of less than 11 is considered an indication for transfer to a dedicated trauma centre.

When used for quality assurance and outcome prediction, a coded form of the RTS is more often used. The coded RTS is calculated as shown next where SBPc, RRc and GCSc represent the coded (c) values of each variable:

\[
\text{RTSc} = 0.7326 \times \text{SBPc} + 0.2908 \times \text{RRc} + 0.9368 \times \text{GCSc}
\]

The coded RTS allows for weighting of the individual components. It is important to note that the significant impact of traumatic brain injury on outcome has been well-emphasised in the coded RTS. Values for the RTS are in the range 0 – 7.8408, where 0 represents being dead and 7.8408 being normal. The RTS is heavily weighted towards the Glasgow Coma Scale to compensate for the importance of major head injury without multisystem injury or major physiological changes. A threshold coded RTS < 4 has been proposed to identify those patients who should be treated in a trauma centre.

**Limitations**

Calculating the coded form of the RTS at the scene of the accident is impracticable, so limiting its usefulness in field triage, whereas, the uncoded RTS is useful for that purpose. The problems inherent in the GCS (and therefore the RTS) include an inability to score accurately those patients who are intubated and mechanically ventilated. Patients under the influence of alcohol or drugs also are difficult to score. Another problem with the RTS is the rapidly changing physiological parameters, as a well-resuscitated patient might score less despite severe injury. The duration of any physiological derangement will also have a profound impact on outcome, but, this fact is not truly accounted for in the RTS or any other method dependent up on it.

To overcome the limitations of the GCS, an alternative approach using the best motor response and the eye-opening response to calculate or predict the verbal response has been used; substitution of the best motor response for the GCS reportedly results in no loss of predictive capability. More recently, it has been shown that the best motor response predicts trauma mortality as well as or better than other trauma-severity scores. In spite of its limitations the RTS has shown a good correlation with probability of survival.

**Acute Physiology and Chronic Health Evaluation (APACHE)**

The APACHE system, which is used widely in ICUs, was introduced in 1981 and has subsequently had two revisions.

It has two components: (1) the chronic health evaluation (CHE), which incorporates the influence of comorbid conditions (e.g. diabetes mellitus,
cirrhosis) and (2) the Acute Physiology Score (APS). The APS consists of weighted variables representing the major physiological systems, including neurological, cardiovascular, respiratory, renal, gastrointestinal, metabolic and haematological variables. The data that are the most abnormal during the first 24 h are used.

The APACHE II (1985) revision restricted the number of comorbid conditions and APS variables from 34 to 12, making the system popular despite its limitations.

### Limitations

The GCS, which comprises a powerful predictive component of the APS, was not intended to reflect extracranial injuries. Being from a relatively younger population, comorbidity is unusual in these patients and there is potential for lead-time bias.

APACHE II underestimates the likelihood of death in patients who are transferred to the ICU after relative stabilisation, as it uses ICU data only and does not account for prior treatment. Patients with trauma are frequently resuscitated in the emergency department or operating room before admission to the ICU. APACHE II is inferior to the TRISS in predicting mortality in injured patients. Poor performance has been attributed largely to the absence of an anatomical component in the APACHE

### Table 2 Trauma-scoring system according to usage

<table>
<thead>
<tr>
<th>Common use of the score</th>
<th>Example</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury description: whole body</td>
<td>AIS (AIS-85, AIS-90: modifications)</td>
<td>Committee on Medical Aspects of Automotive Safety</td>
</tr>
<tr>
<td></td>
<td>Anatomical Index (Al)</td>
<td>Champion et al.</td>
</tr>
<tr>
<td></td>
<td>Anatomical Profile (AP)</td>
<td>Champion et al.</td>
</tr>
<tr>
<td></td>
<td>ISS</td>
<td>Baker et al.</td>
</tr>
<tr>
<td>Injury description: body regions</td>
<td>Organ injury scaling I–IV and revisions (abdominal and pelvic organs)</td>
<td>Moore et al.</td>
</tr>
<tr>
<td></td>
<td>Penetrating Abdominal Trauma Index (PATI)</td>
<td>Moore et al.</td>
</tr>
<tr>
<td></td>
<td>Wagner (lung contusion, CT based)</td>
<td>Wagner et al.</td>
</tr>
<tr>
<td></td>
<td>Tybursky (lung contusion, CT independent)</td>
<td>Tybursky et al.</td>
</tr>
<tr>
<td></td>
<td>Thoracic Trauma Severity Score (TSS)</td>
<td>Pape et al.</td>
</tr>
<tr>
<td></td>
<td>Mangled Extremity Scale (MES)</td>
<td>Gregory et al.</td>
</tr>
<tr>
<td>Clinical course assessment</td>
<td>APACHE I (historical)</td>
<td>Knaus et al.</td>
</tr>
<tr>
<td></td>
<td>APACHE II (most popular)</td>
<td>Knaus et al.</td>
</tr>
<tr>
<td></td>
<td>APACHE III (computational complexities)</td>
<td>Knaus et al.</td>
</tr>
<tr>
<td>On scene and triage</td>
<td>Triage Index</td>
<td>Champion et al.</td>
</tr>
<tr>
<td></td>
<td>AIS</td>
<td>Committee on Medical Aspects of Automotive Safety</td>
</tr>
<tr>
<td></td>
<td>ISS</td>
<td>Baker et al.</td>
</tr>
<tr>
<td></td>
<td>Prehospital Index (PHI)</td>
<td>Koehler</td>
</tr>
<tr>
<td></td>
<td>Revised Trauma Score—uncoded (RTS)</td>
<td>Champion et al.</td>
</tr>
<tr>
<td>In hospital</td>
<td>Revised Trauma Score—coded (RTSc)</td>
<td>Champion et al.</td>
</tr>
<tr>
<td></td>
<td>Acute Trauma Index</td>
<td>Millholland et al.</td>
</tr>
<tr>
<td>Outcome prediction—mortality</td>
<td>ISS</td>
<td>Baker et al.</td>
</tr>
<tr>
<td></td>
<td>Polytrauma—Schussel (PTS)</td>
<td>Oestern et al.</td>
</tr>
<tr>
<td></td>
<td>Trauma ISS (TRISS)</td>
<td>Boyd et al.</td>
</tr>
<tr>
<td></td>
<td>A Severity Characterisation Of Trauma (ASCOT)</td>
<td>Champion et al.</td>
</tr>
<tr>
<td></td>
<td>International Classification of Disease-based ISS (ICISS)</td>
<td>Osler et al.</td>
</tr>
<tr>
<td></td>
<td>New ISS (NISS)</td>
<td>Osler et al.</td>
</tr>
<tr>
<td></td>
<td>Harborview Assessment of Risk of Mortality (HARM)</td>
<td>Al West et al.</td>
</tr>
</tbody>
</table>

### Table 3 Coding variables for the Revised Trauma Score

<table>
<thead>
<tr>
<th>GCS</th>
<th>SBP</th>
<th>RR</th>
<th>Coded value</th>
</tr>
</thead>
<tbody>
<tr>
<td>13–15</td>
<td>&gt;89</td>
<td>10–29</td>
<td>4</td>
</tr>
<tr>
<td>9–12</td>
<td>76–89</td>
<td>&gt;29</td>
<td>3</td>
</tr>
<tr>
<td>6–8</td>
<td>50–75</td>
<td>6–9</td>
<td>2</td>
</tr>
<tr>
<td>4–5</td>
<td>1–49</td>
<td>1–5</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

GCS: Glasgow Coma Scale; SBP: systolic blood pressure; RR: respiratory rate.
Additionally, APACHE II was developed mainly in non-trauma ICU patients who had different clinical problems. In general terms, it is a score that provides guidance about the clinical course of a patient.

The most recent version of 1991, APACHE III, was designed to address many of these issues. The most important modifications were the inclusion of 17 variables; limiting comorbid conditions to those affecting immune function; disease-specific equations, including multiple trauma; distinguishing between head and non-head trauma; and accounting for potential lead-time bias. Practitioners do not widely accept APACHE III, partly because it is proprietary and expensive. In addition, its accuracy needs to be convincingly validated in patients with trauma.

Anatomical scores

Abbreviated Injury Scale (AIS)
The AIS is a way of describing the injury and on its own is not designed to provide any outcome prediction. It forms the basis for the ISS, which in turn forms the basis for other scoring system for outcome prediction. It has undergone six revisions since its first description in 1971. AIS-71 considered only blunt injuries; AIS-85 introduced penetrating trauma. AIS-90 describes over 1300 individual injuries and fine-tunes the severity scores of many other injuries.

The AIS is monitored by a Scaling Committee of the Association for the Advancement of Automotive Medicine. Injuries are ranked on a scale of 1–6 as follows (Table 4).

Each injury in the body is assigned an AIS grade. Various organ injury scales serve the same purpose. Limitations

The score of 5 and 6 represent the ‘threat to life’ associated with an injury and are not intended to provide a comprehensive measure of severity. Despite the vast number of injury patterns described, AIS-90 allows for 13 different types of femoral fractures; it makes no provision for open or comminuted fractures. This fact is important when predicting functional outcome but less significant in mortality predictions.

AIS on its own is unable to predict mortality or other outcomes.

The AIS is also usually assigned rather than derived, and therefore has possible inter- and intra-observer errors. It is not an injury scale, in that the difference between AIS-1 and AIS-2 is not the same as that between AIS-4 and AIS-5.

Injury Severity Score (ISS)
The ISS is an anatomical scoring system that provides an overall score for patients with multiple injuries. Each injury is assigned an AIS score and is allocated to one of six body regions (head, face, chest, abdomen, extremities (including pelvis), and external structures). Only the highest AIS score in each body region is used. The three most severely injured body regions have their score squared and added together to produce the ISS score (ISS = sum of squares of the highest AIS grade in the three most severely injured body regions).

It is important to note that only one injury per body region is allowed. The ISS ranges from 1 to 75, and an ISS of 75 is assigned to anyone with an AIS of 6. Further, the definition of a patient with multiple injuries is one with an ISS greater than or equal to 16 and these require care in a designated trauma centre.

An example of an ISS calculation is shown in Table 5. Limitations

The ISS limits the total number of contributing injuries to three only, one each from the three most injured regions, which may result in underscoring the degree of trauma sustained if a patient has more than one significant injury in either one region or more than three regions. Furthermore, the ISS takes into account only one injury per body region resulting in an inability to account for multiple injuries to the same body region. Therefore a patient’s overall anatomic injury severity is often underestimated, particularly in penetrating trauma. The ISS also it does not take into account physiological variables and gives equal weight to each body region, ignoring two more severe injuries in one body region in favour of a less severe injury in another body region, which fact impairs its ability to predict short-term mortality.

New Injury Severity Score (NISS)
In order to address the limitations of the ISS, Osler et al., developed the NISS, a modification of the ISS. It is defined as the sum of squares of the AIS scores of each of a patient’s three most severe...
injuries regardless of the body region in which they occur.

By preserving the AIS as the framework for injury-severity scoring, the NISS remains familiar and user-friendly. Preliminary studies suggest that it is a more accurate predictor of trauma mortality than the ISS, particularly in penetrating trauma. Also, the NISS has been shown to be superior to the ISS as a measure of tissue injury in predictive models of post-injury MOF.\(^6\)

An example may clarify the differences between the ISS and NISS.\(^7\) Suppose a patient involved in a motor-vehicle crash sustains a steering-wheel compression injury to the abdomen. At laparotomy, a small-bowel perforation (AIS score \(= 3\)) is discovered first: the ISS is now 9, as is the NISS. Next, a moderate liver laceration is discovered (AIS score \(= 3\)): the ISS remains 9, but the NISS increases to 18. Next, a moderate pancreatic laceration with duct involvement is encountered (AIS score \(= 3\)): the ISS still remains 9, whereas the NISS increases again to 27. A bladder perforation is next discovered (AIS score \(= 4\)): the ISS now increases to 16, whereas the NISS continues its climb to 34. Next, a bimalleolar fibular fracture (AIS score \(= 5\)) is discovered. The ISS increases to 20, but the NISS remains unchanged at 34. The NISS thus behaves in a way that is more consistent with a trauma surgeon’s instincts than does the ISS: as injuries increase in number, death becomes more likely, even if these injuries are accumulating in a single body region. Furthermore, adding a relatively trivial injury (fibular fracture) to a different body region should not significantly affect the likelihood of death.

Limitations
Because of the study population used for the development of the NISS, it appears to be more accurate for penetrating injuries. However its claimed better prediction compared to the ISS for patients with blunt trauma has not been conclusively proved.

Like the ISS, the NISS also omits physiological data from the outcome prediction.

The NISS also bears the same burden of requiring a specialist trauma nurse or a trauma surgeon to provide an accurate AIS scoring in order to be more accurate in outcome predictions.

Anatomic Profile (AP)
The AP was developed in response to the limitations of the ISS.\(^26,27\) Unlike the ISS, the AP includes all the serious injuries in a given body region. It also weights head and torso injuries more heavily than those in other body regions. It summarises all serious injuries (AIS \(\geq 3\)) into four categories: category A includes the head and spinal cord; category B encompasses the thorax and anterior neck; category C includes all remaining serious injuries; category D summarises all non-serious injuries. Each component is calculated as the square root of the sum of squares of the AIS scores of all serious injuries within each region. A region with no injury receives a score of zero. Using logistic-regression analysis a probability of survival is calculated. The AP performs better than the ISS in discriminating survivors from non-survivors and may provide a more rational basis for comparing injury severity between patients.

Limitations
Like any other system the AP also has limitations. The two chief reasons for its failing to garner much interest or support appear to be its mathematical complexity and its modest improvement in predictive performance.\(^21,22,27\)

International Classification of Diseases-based ISS (ICISS)
Another, more recent approach to anatomical injury scoring is based on the ICD-9 codes.\(^76,80–82\) This method is termed the ICD-9 Injury Severity Score (ICISS) and uses survival risk ratios (SRRs) calculated for each ICD-9 discharge diagnosis. SRRs

<table>
<thead>
<tr>
<th>Region</th>
<th>Injury description</th>
<th>AIS</th>
<th>Square top three</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head and neck</td>
<td>Cerebral contusion</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Face</td>
<td>No injury</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Chest</td>
<td>Flail chest</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Abdomen</td>
<td>Minor contusion of liver</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Complex rupture spleen</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>Extremity</td>
<td>Fractured femur</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>External</td>
<td>No injury</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Injury Severity Score 50

AIS: Abbreviated Injury Scale.

### Table 5: Example calculation of an Injury Severity Score

<table>
<thead>
<tr>
<th>Region</th>
<th>Injury description</th>
<th>AIS</th>
<th>Square top three</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head and neck</td>
<td>Cerebral contusion</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Face</td>
<td>No injury</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Chest</td>
<td>Flail chest</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Abdomen</td>
<td>Minor contusion of liver</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Complex rupture spleen</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>Extremity</td>
<td>Fractured femur</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>External</td>
<td>No injury</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Injury Severity Score 50

AIS: Abbreviated Injury Scale.
are derived by dividing the number of survivors in each ICD-9 code by the total number of patients with the same ICD-9 code. The ICISS is calculated as the simple product of the SRRs for each of the patient’s injuries.

The ICISS has some advantages over the ISS. It allows all the injuries to contribute to the prediction, and individual injuries are more accurately modelled; it also uses information about all the injuries, together with the patient’s three worst injuries. The ISS, by contrast, is constrained to use only the single worst injury in the three most severely injured body regions. Frequently, this constraint results in the ISS ignoring more severe injuries in favour of less severe injuries that happen to be in a different body region. The use of measured rather than assigned values for injury severity by ICISS also contributes to improved accuracy of prediction.

ICD-9 codes are readily available and their use does not require special training or expertise. Moreover, the ICISS has the potential to account better for the effects of comorbidity on outcome by including the SRR for each comorbidity present.

The ICISS is also more useful than the ISS in predicting other outcomes of interest (e.g. hospital length of stay, hospital charges, resource utilisation). Despite the apparent advantages of the ICISS, it has not yet replaced other methods of outcome analysis. It appears that further validation is needed before it can be used widely.

**Limitations**

Which the ICD-9 codes are used can vary between different hospitals, and therefore it becomes difficult to compare the performance of hospitals. The ICISS also ignores physiological data in its analysis; therefore some trauma centres are very reluctant to use it. Furthermore, computational software is needed to carry out the calculations of predictions. Finally, the claimed improvement of ICISS over ISS is not unique, as ASCOT and AP methods have produced similar results, and thus the ICISS is not conclusively a superior method.

**Combined scores**

**Trauma and Injury Severity Score (TRISS)**

Champion et al. and Boyd et al. have demonstrated that the predictive capacity of any model is increased by the inclusion of additional relevant information in developing of the TRISS. This method combines both anatomical and physiological measures of injury severity (ISS and RTS, respectively) and patient age in order to predict survival from trauma.

TRISS determines the probability of survival ($P_s$) of a patient from the ISS and RTS using the following formula:

$$P_s = \frac{1}{1 + e^{-b}}$$

where ‘b’ is calculated from: $b = b_0 + b_1(RTS) + b_2(ISS) + b_3(Age\ Index)$. The coefficients $b_0$–$b_3$ (Table 6) are derived from multiple-regression analysis of the Major Trauma Outcome Study database. The Age Index is 0 if the patient is below 54 years of age or 1 if 55 years and over. The coefficients ($b_0$–$b_3$) are different for blunt and penetrating trauma. If the patient is less than 15 years old, the blunt coefficients are used regardless of the actual mechanism of injury.

TRISS quickly became the standard method for outcome assessment. It appears to be valid for both adult and child patients.

**Limitations**

The problems associated with the ISS are found in the TRISS also, particularly the inability to account for multiple injuries to the same body region. The TRISS methodology does not take account of pre-existing conditions (e.g. cardiac disease, chronic obstructive pulmonary disease and cirrhosis). These factors are now well known to be associated with a poor trauma outcome. Similar to the RTS, intubated patients are excluded from TRISS because respiratory rates and verbal responses are not obtainable. The TRISS also uses physiological data, which may be unreliable or unavailable.

**A Severity Characterisation Of Trauma (ASCOT)**

Champion et al. introduced ASCOT in 1990 as an improvement over TRISS. ASCOT uses both anatomical and physiological measures. The anatomical variables include AP scores; the physiological variables include RTS parameters (GCS, SBP, RR) from the emergency department. Age (categorised into deciles) is also included in the final calculations. In addition, changes include the individual components of the coded RTS that were included as independent predictors in the final logistic-regression model.

The principal claimed advantage of ASCOT is based on the utilisation of the AP, a better injury-characterisation tool than the ISS, and also

<table>
<thead>
<tr>
<th>Coefficients ($b$) used in determining survival probability in the Trauma and Injury Severity Score</th>
<th>Blunt</th>
<th>Penetrating</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b_0$</td>
<td>-0.4499</td>
<td>-2.5355</td>
</tr>
<tr>
<td>$b_1$</td>
<td>0.8085</td>
<td>0.9934</td>
</tr>
<tr>
<td>$b_2$</td>
<td>-0.0835</td>
<td>-0.0651</td>
</tr>
<tr>
<td>$b_3$</td>
<td>-1.743</td>
<td>-1.136</td>
</tr>
</tbody>
</table>
its ability to consider the impact of physiology. This score incorporates the important observation that an AIS-4 injury of neck is more severe than of the abdomen, and therefore should be appropriately weighted in outcome-prediction models. This amendment was achieved by categorising of the body regions and giving the ascribing according to the region involved. The predictive performance of ASCOT is marginally better than that of the ISS.\textsuperscript{60}

**Limitations**

ASCOT has not been generally adopted, probably because it has provided only slightly improved predictive power over TRISS at the price of substantially increased complexity of calculation.\textsuperscript{60} Moreover, a recent comparison of ASCOT and TRISS scoring found no significant difference between the ROC areas of these two approaches to outcome prediction, confirming that the predictive power of the two methods is equal.\textsuperscript{18}

**Discussion**

The robustness of a trauma-scoring system is very much dependent on the composition of the population under study. As long as a wide range of trauma patients is included, the population scores will perform well. The presence of the very healthy patients who will survive and the very severely injured patients who will almost always die influences the ability of a scoring system correctly to predict outcome. It is the relative number of such patients belonging to the population that determines the system’s performance.\textsuperscript{9,10,12,42,44,64,69,91,94,95,97,100,103} In this respect the debate over blunt as compared to penetrating injuries is a very valid one, as it reflects the existing differences between different centres and countries.

Another important aspect is the care process for the trauma victims and how it reflects on outcome prediction. Rutledge\textsuperscript{79} demonstrated that the ISS is a flawed instrument for defining the severity of injuries because it depends at times on outcomes that may be influenced by the care process. The described several scenarios in which an initially less severe injury, when mismanaged, leads to a more severe ISS score than should have been the case. In so doing, the score would mask the occurrence of poor care, which might otherwise have been detected by a scoring system that did not depend on the outcome of hospital treatment.

The description of the injury should be accurate enough to reflect its true severity. In this regard there are possible sources of errors, that one must consider to analyse critically the outcome results. Take, for example, an error in ISS classification, such as a ‘minor’ carotid or iliac arterial laceration that may initially be unrecognised. This fact will have impact on outcome, but would have not been documented as part of the initial scoring of ISS.

The classification of severity as in the TRISS method for calculating probability of survival also requires physiological data, and such data are more significant, when abnormal, in driving the outcome estimate than is the ISS. Minor errors in ISS classification produce relatively small changes in survival probability if patients have major physiological derangements. It is possible that the problem of misclassification would be avoided if ISS assignment were done 24 h after admission, or after the initial diagnostic assessment and/or surgery, rather than at the end of the hospital admission.

A scoring system should be able to take account of various injury severities on their own merits for their ability to contribute to the outcome. To illustrate this point, an AIS grade 3 injury of the thorax may contribute more to mortality than an AIS grade 3 injury of an extremity. Diverse combinations of injury severity and specific injuries may lead to the same ISS value yet very different risks of mortality. The TRISS\textsuperscript{11} method and the ASCOT\textsuperscript{15} severity score, in particular, were intended to counter some of these limitations of the ISS. Additionally, the ISS weights injuries to each body region equally, ignoring the importance of head injuries in mortality from trauma. Furthermore, mortality is not strictly an increasing function of the ISS. The mortality rate for an ISS of 16 can be higher than the mortality rate for an ISS of 17 because of the different combinations of AIS scores that comprise each. Another idiosyncrasy of the ISS is that many ISS values cannot occur, while other ISS values can result from multiple different combinations of AIS scores. Obviously, this makes the ISS a heterogeneous score and reduces its predictive ability.

Anatomical, or combined scores require a completed diagnostic process and cannot be calculated at the site of the accident.\textsuperscript{9} At the end of the diagnostic procedures in the emergency department a first scoring is possible. For the correct classification of the severity of injury, anatomical scores have to be recalculated after the completion of a full diagnostic assessment in order to consider primarily missed diagnoses in the emergency department.\textsuperscript{103}

The available trauma scores have been used for predicting outcomes other than mortality. For example, the ISS has been found a consistent risk-factor predictor for post-injury MOF.\textsuperscript{86–88,90,92} In developing predictive models for MOF, researchers categorised risk factors as those related to tissue-injury severity, cellular-shock severity, the magnitude of the systemic inflammatory response to
the injury, \(^3\) and host factors (e.g. age, \(^{51,95}\) sex, comorbidity). Tissue-injury severity is a major component of these predictive models, and it is quantifiable using the ISS. However, on recognising the limitations of the ISS, researchers subsequently investigated the AP\(^{27}\) as an alternative measure of tissue-injury severity and found, that it offered no advantage over the ISS in predicting post-injury MOF. Moreover, they found the AP is difficult to calculate, with greater inter-rater variability than the ISS. More recently, the NISS has been shown to be better than the ISS in predicting post-injury MOF.\(^6\)

Categorisation of the extent of post-traumatic disability is meaningful for physicians who deal with trauma patients, policymakers and insurance companies. Such data not only provide insight into therapeutic strategies, but also into the economic and social consequences of trauma, and will help to determine policies about social security and national health care.\(^{99,100}\) Little is known about the final functional outcome of patients with multiple injuries, how fast they recover, and how many of them have residual disabilities. Such information is of importance, because we know that trauma patients are young\(^{34,35,45,46,48,70,78}\) and that the majority belong to the working population. It is clear that many of them may make a long-term appeal for social security. Insight into injury characteristics, recovery, and the extent and nature of residual disabilities may lead to changes in treatment policies. The available scoring systems make very little contribution in this aspect. However, several generic health-outcome instruments (SF-36, SF-12, etc.) exist, which are being used for this purpose. Perhaps there is a need for the development of one trauma-specific functional-outcome score.

The effect of pre-existing diseases on trauma outcome has been discussed in the past\(^{69}\) and the scoring system should take them into account. However, the available systems have failed fully to take this fact into account, leaving a field open for further research.

We must hope that continued research will improve our methodology and make accurate trauma prediction a reality. Until that time, we should use existing severity scores with great caution for purposes for which they were not intended (e.g. decisions to withdraw support or allocate limited resources).

**Conclusion**

Several trauma-scoring systems have been developed over the past 30 years. It appears that currently there is no universally acceptable and applicable scoring system that takes into account all the issues discussed here. Nevertheless, with improved injury description using the AP and AIS-90; a more reliable anatomical data are now available, which has made our ability to predict outcome more scientific. However, early and late mortality after trauma depend not only on the anatomical injury, but also on the amount and duration of physiological derangement, the latter playing the a vital part in post-trauma MOF and late deaths. Therefore the addition of physiological data to the scoring system is essential.

The improved ISS and TRISS method has shown promise despite the drawbacks mentioned above. The NISS method also demonstrated assurance, but has not been proved conclusively a better system that will become universally acceptable.

ICD-9-based scores (ICISS and HARM) have yet to prove conclusively better than other methods. Individual body-region injury characterisation has improved significantly with the availability of well-accepted organ injury-scoring systems. However, other factors such as 'patient reserve' play an important part in outcome, this concept includes age, co-morbid conditions, immunological responses to trauma and possibly genetic predisposition.

No, currently available system is able to incorporate all these aspects into an outcome-prediction score. The task for the future is to develop a system that incorporates different severity of multiple injuries and accounts for population differences including 'physiological variability', care processes and rehabilitation processes. Until such a system is constructed, we should be cautious in our use of the existing trauma-scoring methods.

**References**
