TITLE: MESUREMENT OF THE MAGNITUDE OF INJURY: A REVIEW OF THE TRAUMA SCORING SYSTEMS

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ABSTRACT
Background: *Trauma scoring systems are a vast, ever expanding and often confusing field. There is a need for trauma surgeons, residents and all who manage trauma to be conversant with the more frequently used systems in order to be able to appreciate changes in trauma care emanating from trauma research.*

Objective: *To review the current trauma scoring systems with a view to highlighting their various bases, strengths, weaknesses and areas of applicability.*

Methods: *Literature review of the current trauma scoring systems was done using textbooks, journals and internet searches mainly with pubmed and Medline.*

Results: *There are a plethora of trauma scoring systems. All have their various strengths and weaknesses. Different systems perform differently in different situations depending on which outcome parameter is of interest. The more frequently used systems such as the AIS, ISS and TRISS are discussed in detail.*

Conclusion: *Although trauma scores are not designed for clinical decision making in individual patients, a good understanding of the basis of the more commonly used systems will enable doctors involved in the care of trauma patients to appreciate changes in patient care algorithms emanating from trauma research.*

Key Words: *Injury severity, outcome, Polytrauma, probability, survival, trauma*

Introduction

Doctors treating injured patients have always been interested in finding an objective way of quantifying the severity of injury sustained by a patient. Such assessment was initially done empirically, depending on the judgment and experience of individual physicians[1]. This practice of course was fraught with many shortcomings as there was no objective uniformity in injury description. When different clinicians say that an injury is severe, there is no guarantee that both are describing the same magnitude of injury. It therefore became obvious that there was a need to develop a system that would bring about as much uniformity in description and quantification of injuries as possible. This science can be said to have taken off effectively with the description of the Abbreviated Injury Score by the American Association for Automotive Safety in 1969 and has undergone tremendous developments in that period[2].

Injury scoring is defined as the process of quantification of risk of an outcome following trauma[1]. Several variables influence the outcome of trauma. Some of these are personal to the patient and others are not. Variables personal to the patient include the magnitude of anatomical disruption occasioned by injury, the degree of physiological derangement and health status of the patient prior to injury. All trauma scoring systems incorporate these variables in isolation or in combination to try to predict outcome. Variables that are not personal to the patient include the interval between the injury and presentation to hospital, interval between presentation and definitive care, expertise of physicians and hospital, type of treatment, type of trauma system within which care took place and so many other variables. The aim of injury scoring is to stratify the risk due to variables which are personal to the patient so that variables which are not personal to the patient may be studied[3]. It is the process of stratifying these variables which are personal to the patient that provides a measure of quantification of the magnitude of injury that the individual patient has sustained. An objective and uniform description of the variables personal to the patient makes it possible to evaluate the contribution of the variable not patient to different possible outcomes. It is this uniformity in injury characterization that forms the basis of the trauma scoring systems.

Uses of trauma scores

Trauma scoring systems study outcome. Several outcome parameters may be of interest following trauma. The first is usually survival. This is the proportion of patients who live following an injury. The corollary parameter is mortality or death, connoting the proportion of patients who die from an injury. Other outcome parameters include complications, need for intensive care unit (ICU) stay, the length of such ICU stay, length of hospital stay, quality of life after trauma and cost of treatment. The outcome measures of interest are many and varied and trauma scoring systems form the backbone of trauma research generally.

Perhaps the most frequently studied outcome parameter is survival. Increased magnitude of injury sustained portends an increased likelihood of death and thus decreased survival following trauma. Such patients therefore require care at a specialized centre in order to improve their chances of survival. It is an established fact in trauma care that patients managed at specialized trauma centres have better outcomes than those who are not[4]. The earliest trauma scores were designed for field triage.[3] A score associated with increased probability of death implies that the patient requires urgent transport to a designated trauma centre to improve chances of survival. Scores used for field triage should be easy to derive and simple to apply as well as being able to predict the probability of death with reasonable accuracy.

Trauma scores can also be used to compare the outcome associated with different modalities of therapy. It could be used to study outcome of care between individual doctors within the same institution or across institutions. It is also a useful tool for general audit of care in an institution. It can also be used to compare outcome of care between hospitals, regions or countries. It could also be used to establish a set point for inter-hospital transfer e.g. to a level I trauma centre, a regional trauma centre or a neurosurgical centre. Administrators are also interested in trauma scores because of the cost implications of trauma on the institution and issues relating to rational health resource utilization and allocation[5]. Trauma scores can also be used to evaluate the performance of trauma systems. Automotive industries and trauma prevention strategists are also interested in trauma scores. The demonstration of reduction of injury severity as well as mortality following vehicular crashes propels both engineering research and design changes for improved vehicular safety. Such changes have seen such features as seatbelts, air bags, ABS brake systems etc become standard features of cars. Similarly demonstration of decreased injury severity with introduction of prevention intervention can drive changes in legislation and enforcement. The demonstration of a reduction in the mortality and severity of injuries sustained following motorcycle crashes with the introduction of crash helmets led to a legislation enforcing the use of helmets in the city of Seattle in the US state of Washington in 1995[6].

Statistical Basis

Trauma scores are usually derived from analysis of trauma data banks such as the (American) National Trauma Data Bank (NTDB) as well as other trauma registries. One of the largest of such trauma registries is the data from the Major Trauma Outcome Study (MTOS) [7] from which several scoring systems were derived. Trauma scoring systems generally try to predict the probability of an outcome (e.g. survival) following trauma. Statistical concepts employed include the odds ratio, survival risk ratio etc. Frequently they involve the use of statistical tools such as multiple logistic regression analysis to attempt to compute the relative input of each variable to the outcome of interest.

Classification

Injury scoring systems may broadly be classified as anatomical, physiological or combined depending on which types of parameters are used to generate them.

Anatomical Scores

This scoring system takes into account the magnitude of anatomical disruption following trauma. They do not take into account the degree of physiological derangement ensuing and therein lies a fundamental weakness.

Abbreviated Injury Score (AIS)

This is perhaps the oldest, simplest and most popular of the anatomical scoring systems. It was developed for the American Medical Association Committee on Medical Aspects of Automotive Safety and was first introduced in 1971. It is an ordinal scale that divides injuries into six categories based on degree of threat to life.[8,9].

1 Minor
2 Moderate
3 Serious (survival expected)
4 Severe (survival uncertain)
5 Critical (survival not expected)
6 Unsurvivable

Type 1 injuries are trivial or superficial injuries and type 6 injuries are such injuries as decapitations and hemi-corporectomies which are considered uniformly fatal. In between these there is a lot of subjectivity in the allotment of scores based on the AIS. AIS measures the threat to life of an injury and is not an objective description of the injury itself. It is therefore assigned rather than derived. It still does have issues of inter-observer variability. What is moderate injury to one observer may appear as severe to another. Again the AIS is not a linear scale. The difference between type 1 and type 2 injury is not the difference between type two and type 3 and so on. These constitute some of the limitations and weaknesses of the AIS. The strengths of the scoring system however are that it relatively easy to derive and use. It enjoys a lot of popularity and forms the basis of the Injury Severity Score [10]. It has undergone several revisions and the most recent; the AIS 90 describes over 1300 injuries.

Injury Severity Score (ISS)

This scoring system was introduced by Susan Baker and co-workers in 1984[10]. It is used primarily to describe injury severity in patients with polytrauma or multiple injury. It divides the whole body into six anatomical regions viz:

1 head and neck
2 face
3 chest
4 abdominal and pelvic cavities
5 pelvic girdle and extremities
6 external (skin)

$ISS \leq AIS\,(A)^2 + AIS\,(B)^2 + AIS\,(C)^2$

In a patient with polytrauma, the AIS score is allocated to each of the injured body regions. Only one injury per region is scored. Where two or more injuries are present in one region, the most severe one is scored. The ISS is then calculated by adding up the sum of the squares of the three most severely injured regions. The maximum score, if the unsurvivable injury is excluded, is 75 (i.e. 5^2 in 3 regions) therefore any patient with any injury assigned an AIS score of 6 is assigned an ISS score of 75 irrespective of other injuries.

The ISS has found popularity among physicians in the quantification of polytrauma. Major trauma is currently defined as an ISS of 16 and above and is associated with mortality in excess of 10%[11]. The ISS correlates well with not only mortality, but also morbidity, length of hospital stay and some other outcome parameters. The ISS enjoys the same advantage of the parent AIS being easy to calculate and use and also being a good predictor of survival especially among multiply injured patients. It also inherits some of the disadvantages of the AIS not being a linear scale. In addition it has weaknesses of its own. Primary among these is the failure to recognize multiple injury within one anatomical region, and the lumping together of different regions into one such as head / neck and abdominal / pelvic cavities. A second injury within an anatomic region while not scored may be of greater severity than another injury in a different region which is scored and may have a greater influence on outcome. The patient therefore has a lower score even though harboring more severe injury. Another major weakness is that there are 44 possible combinations of ISS score and similar ISS scores are possible with different injury patterns. A score may therefore not be unique to an injury pattern or severity for that matter. The fact that a full catalogue of the patients injuries only become available after full resuscitation and/or operation means that ISS is not good for triage purposes, especially in the field.

New Injury Severity Score (NISS)

This was introduced by Osler in 1974 to improve on the weaknesses of the ISS especially the failure to take into account, multiple injuries in one region [12]. It therefore considers the three most severe injuries irrespective of body region involved. It still makes use of the AIS score like the ISS and is calculated in the same manner. It has been found to outperform the ISS in predicting survival among polytraumatized patients[13]. It suffers the weaknesses of the AIS and the fact that certain injuries which are not as severe are not taken into consideration and these may influence certain outcomes. Although superior to the ISS in predicting survival, it has failed to replace it or enjoy similar popularity among clinicians.

The Anatomic Profile Score (APS)

This was introduced by Copes et al in 1990 to try and overcome some of the limitations of the ISS and NISS particularly the exclusion of certain injuries [13].

An attempt is made to incorporate all injuries in a body region. A second feature of the APS is the effort to 'weight' injuries to certain parts like the head and torso more heavily than other injury to other regions. The basis was the knowledge that injuries to certain body regions tend to have greater contribution to adverse outcome than others. It uses the following formula to calculate the score.

$APS \leq .3199(mA) + .4381(mB) + .1406(mC) + .7961(mD)$

Where:

- $mA \leq$ quantification of head / spine injuries
- $mB \leq$ quantification of chest and neck injuries
- $mC \leq$ Quantification of all other serious injuries
- $mD \leq$ Quantification of all other non serious injuries

Each component (A, B C or D) is the square root of the sum of the squares of all injuries in that group. Serious injuries are those with AIS 3 to 6, while non-serious injuries are AIS 1 and 2. A region with no injury is scored 0. The APS is more comprehensive in that it does not leave out any serious injury, and in fact considers non serious injuries too, and also gives appropriate weight to the body regions. It performs better than the ISS in discriminating between survivors and non-survivors[13] but has however not been able to replace the ISS, probably because of its complexity in calculation.

Penetrating Abdominal Trauma Index (PATI)

Introduced by Moore and colleagues in 1981, this system calculates the risk of complications following laparotomy for penetrating abdominal injury. It takes into consideration a maximum of 14 organs which are examined at laparotomy and assigned a risk factor ranging from 1 to 5. Injuries to organs are then graded from 1, for the most trivial injury to 5 for the most severe. The sum of the product of the severity grade and risk factor for all organs gives the PATI Score. The higher the PATI, score the greater the expected rate of complications and a PATI score of 25 is associated with more than 50% complication rate.[14]

International Classification of Diseases Map -90 (ICDMAP-90)

This system, introduced by Mackenzie and co workers in 1997 'maps' International Classification of Disease - 9 codes to corresponding AIS values from which ISS, NISS and AP scores may then be calculated. It has found wide use in the evaluation of trauma systems [15-17]. Its disadvantages include the fact that some ICD-9 scores do not have corresponding AIS scores and the fact that it is a proprietary software, making it expensive to acquire.

International Classification of Diseases derived Injury Severity Score (ICDISS)

Here the survival risk ratios (SRR) are calculated for each ICD-9 code of injury. The SRR is the number of patients with a particular injury who survive divided by the total number of patients who have that injury. Osler and co., who first introduced this system, defined the ICISS score as the product of the SRRs for all injuries [18]. Hence;

$$ICISS \leq (SRR)_{injury1} \text{ x } (SRR)_{injury2} \text{ x } (SRR)_{injury3} \text{ X } (SRR)_{injury4\ldots}$$

Its major advantage is that it is calculated and therefore more objective than the consensus derived AIS which is assigned. In addition, all injuries contribute to the final score and not just a few. This makes it a powerful predictor of survival and it is indeed a better predictor of outcome than ISS. It suffers the limitation of being 'tainted' by coexisting injuries because SRR is calculated for specific injuries and some injuries rarely exist in isolation [19]. A second limitation is that the ICD codes are institution specific, therefore comparisons between hospitals may not be objective. Again, this requires a proprietary software to calculate.

Trais

This is the product of AIS and SRR and behaves like the ICISS. It out predicts the AIS derived scores for mortality [1].

Maximum AIS Score (MAXAIS)

This calculates the probability of survival using the maximum AIS score. It has been found to be a better predictor of mortality than systems incorporating inputs from multiple injuries [19].

Organ Injury Scale (OIS)

The organ injury scale was introduced by the American association for the study of trauma in 1990 based on the original extensive work of Ernest Moore[20] and co workers. It is a descriptive system applicable to specific organs and typically grades injuries from 1 (minor) to 5 (most severe). It is not a scoring system and has not been used to calculate outcomes but shows the promise of this application.

The Physiologic Scores

These take into account physiological parameters in calculating magnitude of trauma. The failure to take into consideration the severity of anatomical disruption constitutes a major weakness.

Glasgow Coma Scale

This is perhaps the earliest physiological scoring system and was introduced in 1974 by Teasdale and Jennett [21]. It takes into consideration three parameters namely: the eye opening, the best verbal response and the best motor response. The minimum score is 3 and the maximum is 15. Based on GCS scores, head injury may be classified into mild (13 15), moderate (9 12) or severe (3 8). It has also been modified to suit the paediatric population. Lower scores denote more severe injuries and correspond to higher risk of mortality. It is primarily used to describe head injuries but actually assesses brain function. The motor component is as good a predictor of outcome as the full score if not better [22] and may be used alone when the other parameters cannot be fully assed (e.g. local eye injury, severe facial swelling, endotracheal intubation, tracheostomy etc). These constitute the major weakness of the GCS; otherwise, it is a powerful predictor of mortality in head injured patients.

Trauma Score (TS)

This was first described by Champion et. al. in 1981. It takes into account the respiratory rate, respiratory expansion, systolic blood pressure and capillary refill. Each parameter is assigned a range of values and these are summed up to give the total TS score. The lowest score is 0 and the highest is 16. The lower the score, the more severe the physiological derangement. A TS of 5, 10 and 15 is associated with a probability of survival of 4%, 55% and 98% respectively. The TS is easy to derive and has found good use in field triage as well as assessment of intervention in the pre hospital setting.[23]

Revised Trauma Score (RTS)

This was introduced by Champion et al. in 1983 as a refinement of the TS. It incorporates three parameters namely; GCS, systolic blood pressure and respiratory rate into a single score[24, 25]. The non weighted RTS is a very useful field triage tool as it has a very powerful association with survival. A RTS of 10 or less is associated with up to 30% mortality and prompts immediate transport to a level I trauma centre. When weighted, the respiratory component is multiplied by a coefficient of 0.2908, the systolic blood pressure by 0.7326 and the GCS by 0.9368. The coefficients are derived by logistic regression and when summed, give scores that range from 0 to 7.8408, the lower values representing more severe injuries. This weighted score performs well in outcome predictions. Like the TS before it, it suffers some limitations however. Physiologic parameters are dynamic and measurements represent a snapshot of an evolving process. It is not possible to say if the measurements were taken before compensatory mechanisms have been fully deployed, at its peak or during the phase of decompensation. The blood pressure especially is notorious for its inability to predict outcome on its own[11]. Again, RTS fails to take into consideration some other physiological parameters, changes in which may influence the outcome of trauma, and it has not been validated for both extremes of age. The GCS component saddles it with the burden of being incalculable in patients who are intubated, tracheostomised, or have complex facial injuries or edema.

Coded value	GCS	SBP(mmhg)	RR(breaths/min
0	3	0	0
1	4-5	<50	<5
2	6-8	50-75	5-9
3	9-12	76-90	>30
4	13-15	>90	10-30

Revised Trauma Score.

Acute Physiology And Chronic Health Evaluation (APACHE)

This system was introduced in 1981 as a way of predicting the risk of mortality in critically ill ICU patients. It has two components: Acute Physiologic Score (APS) and a Chronic Health component [26, 27]. The acute physiologic component comprises weighted variables for physiologic systems such as the cardiovascular, respiratory, neurologic, renal, haematologic and gastrointestinal. The chronic health evaluation component takes cognizance of co-morbidities such as heart disease, diabetes mellitus, cirrhosis, malignancy etc. APACHE is complex to calculate, is proprietary and therefore expensive, and is inferior to TRISS in predicting outcome for trauma patients[28]. It was derived from ICU data of predominantly non-trauma patients and this perhaps might partly explain its limited use in trauma. Even among trauma patients it fails to take cognizance of pre-ICU treatment in the Emergency Department and /or Operating Room and therefore underestimates mortality. Although in its third revision now (APACHE III) [29] the most popular is the second - APACHE II[27].

Combined Scoring Systems

These systems attempt to improve outcome prediction by generating scores based on inputs from anatomical and physiological systems as well as using age adjustment. In so doing they have improved prediction but at the expense of ease of calculation. They have not achieved the desired perfection in outcome prediction and have not replaced some of the older scores.

Trauma and Injury Severity Score (TRISS)

The TRISS methodology was introduced by Champion et al. in 11987 using data from the Major Trauma Outcome Study. It combines the anatomical ISS, the physiological **R**TS and the patient's age. It calculates the probability of survival Ps, using two equations: one for blunt and one for penetrating mechanisms of injury [30]. The equations incorporate the three parameters which are weighted by coefficients derived by logistic regression. The age component is parsed into two: 55 and below, and above 55. TRISS is defined as the sum of the weighted components and is expressed as the probability of survival (Ps).

$$Ps \leq 1/1+e^{-b}$$

Where:

$$b \leq b0 + b1\ (RTS) + b2\ (ISS) + b3\ (\text{Age Index}).$$

The coefficients ***b*** are derived by logistic regression analysis from the MTOS data. The TRISS methodology is a good outcome predictor, appears consistent for both adults and children and consequently has gained a lot of popularity in outcome assessment. It has also been found very useful in identifying unexpected deaths and unexpected survivals. It however inherits limitations of the ISS component. Moreover the equations require many components to calculate and the absence of a single component renders the equation incalculable [31, 32]. Trauma registries are notorious for incomplete or missing information and that tends to render TRISS inapplicable. TRISS is also a very poor predictor of outcome of penetrating torso trauma.

A Severity Characterization of Trauma (ASCOT)

This was introduced by Champion and co. in 1996 to try to overcome some of the limitations inherent in TRISS; particularly the weaknesses of ISS and unreliability in penetrating torso trauma[33]. It is similar to the TRISS methodology and was also derived from the MTOS database, but however uses the APS in place of the ISS for the anatomic component of the score, therefore obviating some of the weaknesses of ISS. Patient age is also divided into five categories instead of two. RTS component of TRISS is retained. ASCOT is also expressed as a probability of survival, which represents the sum of the weighted components in the equations. It does out-predict TRISS for survival but has failed to supplant it [1], probably because it is more complex to derive.

Trauma Scoring In Children

Several attempts have been made to provide for the peculiarity of the paediatric age group in injury scoring. This is because of the recognition of the fact that several of the values used in the standard scoring systems are adult values. Also, because of the relative size of the child and their limited physiologic reserves, weight becomes a factor. The Glasgow come score has been modified to provide for children under five **the paediatric GCS**[34]. Here the verbal response is divided into: 1- no response, 2- crying, irritable and inconsolable, 3- crying but inconsistently consolable, 4- consistently consolable and 5- calm interested and follows objects with the eyes. All other parameters are scored similar to the GCS. The ISS has been modified to make it applicable to children **the Modified Injury Severity Score (MISS)** [35]. It is scored like the ISS except that the injury severity is graded 1 to 5 and the body regions considered are 5 namely, neurological, face and neck, chest, abdominal and pelvic contents and extremities and pelvic girdle. **The Paediatric Trauma Score (PTS)** [36] uses different parameters namely; size (weight), airway, systolic blood pressure, central nervous system, open wound and fracture to quantify injury severity in children. It has been found a good predictor of survival but does not perform better than the RTS and so has not replaced it in children.

Other Scoring Systems

There are many other scoring systems which are not as popular as the ones discussed. **The Systemic Inflammatory Response Syndrome (SIRS) Score** [37] is not limited to trauma but is a general measure of host response to non-specific injury. It uses the following parameters: body temperature, respiratory rate, pulse rate and white blood cell count. It ranges from 0 to 4 and a score of 2 and above is indicative of systemic inflammatory response syndrome. The **Sequential Organ Failure Assessment Score (SOFAS)** [37] is used mainly in ICU patients to monitor organ function and rate of deterioration or improvement. The parameters assessed are the respiratory, the cardiovascular, haematological, renal, neurologic and gastrointestinal systems. The Glasgow Outcome Score (GOS) gives an outcome grading of brain injury. **The CRAMS Scale**[38] measures **c**irculation,

respiration, **a**bdomen, **m**otor function and **s**peech. Others include the Triage Index (TI), Illness-Injury Severity Index (IISI), Trauma Triage Rule (TTR), Mangled Extremity Severity Score (MESS), the Revised Estimated Survival Probability Index (RESPI) and the Harborview Abbreviated Risk of Mortality (HARM). These are earlier systems that did not gain popularity because of one defect or another. Two new systems do show some promise however: these are the **MGAP system** (Mechanism, GCS, Age and arterial Pressure) and **EMTRAS Emergency Trauma Score** which uses the purely physiologic parameters of age, GCS, base excess and prothrombin time. Although both have been shown to be good predictors of mortality, and therefore excellent triage tools, validation and comparison to the established scoring system is still being awaited[39, 40].

Conclusion

Although a plethora of trauma scoring systems exists, the perfect score is yet to be found. This is partly due to the difficulty in controlling for the multitude of variables that impact on trauma outcome. Scores have different strengths and weaknesses and therefore find applicability in varying situations depending on which outcome variable is being studied. With improved advances in understanding trauma there is no doubt that newer scoring systems will evolve and backed by more powerful statistical tools, outcome prediction is likely to improve in the future. The clinician who manages trauma patients will be best served to appreciate these scoring systems and their areas of application as they form the basis of trauma research which drives changes in best practices. It is however strongly recommended that in the hospital setting, decisions concerning individual patients be made mainly on clinical grounds and not rely solely on their trauma score.

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