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Chapter 14
Injury Severity Scaling

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Introduction

The notion of injury severity traces back to the book of Genesis (3, 15), where it is stated that "[God] will put enmity between you [the snake] and the woman, and between your offspring and hers; [the woman's offspring] will crush your head, and you will strike his heel." The term "injury severity," however, was not used in an easily accessible research publication prior to a paper on aviation safety in 1962 (Pearson 1962). Ten more years elapsed before another indexed publication, this time on motor vehicle research, captured this term (Siegel 1972), even though one could claim an earlier publication using the term (Committee on Medical Aspects of Automotive Safety 1971) which is not indexed and thus not found in PubMed. Since then, more than 12,000 indexed papers (Pubmed accessed March 5, 2011) and countless other publications have included this term. Yet the actual meaning of the term "severe" as it applies to injury has never been formalized.

"Severity" is a word derived from Latin that describes the quality or condition of being "severe," which in turn implies "harsh, strict or highly critical, as in treatment, serious or grave"[1] (Guralnik 1986). Thus, in relation to injury, "severity" is a comparative term used in regard to a number of criteria including mortality risk, the need for more timely or more intensive care, or the risk of complications or lasting limitations in the future. That is, severity measures allow us to describe injuries above and beyond their existence or frequency (as with measures presented in the previous chapter) or to describe their long-term functional outcomes or even costs (described in separate chapters later in this book). Severity measures may have been included in any of the injury surveillance systems described elsewhere in this book, or they may be applied to special data collection efforts targeting

[1] In other Latin-derived languages, such as Spanish, the term "*grave*" is preferred to the term "*severo*" when using this concept as it applies to injury.

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specific hypothesis testing. They may be used as outcome measures themselves when evaluating trends over time in effectiveness of different interventions, or they may be used as possible confounders (or case-mix adjusters) when evaluating the relationship between independent variables and any other outcome. In clinical settings, severity measures can be used in a variety of applications, including triaging (see Chap. 15), application of clinical guidelines, and prioritizing injuries amenable to environmental intervention, such as redesigned interiors of motor vehicles.

In 1984, MacKenzie summarized the then state-of-the-art severity measures as discussed in a conference on trauma indices cosponsored by the US National Center for Health Services Research and the American Trauma Society (Mackenzie 1984). In that meeting, criteria to evaluate the scales were developed, several scales were reviewed and the most promising ones identified, and, notably, three major reasons to develop and use these scales were characterized: (1) regionalization of trauma care (and, because of that, field triage), (2) policy development and funding (with related planning and retrospective evaluation), and (3) assistance in the development of intensive care units (with involvement in prognostic assessment and monitoring of patients in these units).

Since that 1984 publication, a few textbooks have included specific reference to the topic of injury severity measurement, either as a substantial component of a chapter (Berger and Mohan 1996, Chap. 2) or as full chapters (O'Keefe and Jurkovich 2001; Segui-Gomez 2007). Of the manuscripts that have been devoted to related issues, such as the choice of best scoring system to predict outcome after multiple trauma, we highlight Chawda et al. (2004).

In this chapter, we will present a concise description of the criteria or dimensions relevant to the development and application of injury severity measures, describe a selected number of them as well as the methodological implications related to their use, and suggest future areas of work.

Description of Dimensions Relevant to Injury Severity Scales

The growing number of injury severity scales over the last 50 years reflects the recognition of the importance of severity classification for patient care, resource planning, design of injury reduction interventions, and cost and effectiveness evaluation of injury prevention measures. Each scale has been developed according to specific aims that are not necessarily shared by the other systems, which can make the scales conceptually quite different. This chapter describes the most commonly used injury severity scales that apply to a broad range of patients, injuries, and injury mechanisms according to selected dimensions. The goal is that the reader may gain from the subsequent paragraphs a clear understanding of the development of each scale and guidance in selection of the appropriate scale to be used in a particular situation.

The selected dimensions are grouped into two different categories: those related to development of the scale and those related to usage and application of the scale. While a detailed description of the selected injury severity scales is given in the following section, we summarize here how each scale relates to identified dimensions. Table 14.1 shows the acronyms and full names of the injury scales selected to be discussed throughout this chapter.

1. Dimensions considered in the development of the scales:

   - Population: whether the scale applies to people of all ages (to date, no scale has been developed targeting just one of the two genders).
   - Injury nature: are all types of injuries included in the system? Or does it exclusively address head injury, long bone fracture, or others?
   - Injury mechanism: was the scale developed to describe a single injury mechanism (e.g., motor vehicle crashes, falls, drowning) or is it applicable to several or all of them?
   - Outcome: which is the outcome targeted by the scale (e.g., death, length of treatment, impairment)?

Table 14.1 Acronyms and full names of the injury severity systems described in the chapter

Acronym	Complete name
KABCOU	None specifically
AIS	Abbreviated Injury Scale
MAIS	Maximum AIS
ISS	Injury Severity Score
NISS	New Injury Severity Score
AP	Anatomic Profile
GCS	Glasgow Coma Scale
RTS	Revised Trauma Score
TRISS	Trauma and Injury Severity Score
DCP	Damage Control in Polytrauma
ICISS	International Classification of Injury Severity Score
HARM	Harborview Assessment for Risk of Mortality Score

- Observation unit: whether the scale evaluates the severity of a single injury or the likely overall effect of all the injuries in one subject.
- Anatomical/physiological description: is the scale based on anatomical or physiological data or both?
- Goal: does the scale predict or measure the outcome?
- If the objective is to predict outcome, was this prediction based on real data or expert judgment? This dimension relates to how the injury score was assigned to the injuries (whether based on the opinion of experts assessing, for example, threat to life, or real data used in calculating probability of death).
- If there is a prediction, has the scale been validated against real-world data?
- Has the measure been validated in regard to reliability and other scale psychometric properties?
- Source: whether the score is developed by collecting original data (primary) or is based on preexisting data, for example, codes collected for other related or unrelated purpose (secondary).
- Dynamic/static: does the score evolve over time or remain the same regardless of the evolution of the patient?

2. Dimensions to be considered in the use of the scales:

- Continuous/categorical: the type of statistical values describing the severity score that the variable creates.
- Best summary statistics: which statistics are recommended for use with that particular injury metric?
- Translation into other scales: is that scale used to derive other injury severity scales?
- Scenario (where the scale is applicable): whether it can be applied at the scene of injury to influence initial triage to a certain type of care, or during patient care (e.g., at hospital or intensive care unit), or only retrospectively.
- Applications: whether the scale can be/has been used in field triage, in evaluation and planning, in clinical assessment and monitoring of patients, or in biomechanics research on injury thresholds.

Table 14.2 summarizes the information relating to the dimensions involved in the development of each injury severity system and Table 14.3 describes the main factors to be considered in the use and application of each scale.

Table 14.2 Comparison between selected injury severity scales across dimensions relevant to their development

Acronym	Population	Injury nature	Injury mechanism	Goal	Outcome	Observation unit	Anatomical/ physiological description	Real data/ expert judgment	Source	Dynamic/ static	Validation
KABCOU	All	All	All	Measure	Death, impairment	Person	None	Real data	Primary	Static[a]	None
AIS	All[b]	All	Impact, penetrating, blast	Predict	Death and others	Injury	Anatomical[c]	Expert judgment	Primary, secondary (ICD)	Static	Some
ISS	All[b]	All	Same as AIS	Predict	Death	Person	Same as AIS	Same as AIS	Secondary (AIS)	Static	Some
NISS	All[b]	All	Same as AIS	Predict	Death	Person	Same as AIS	Same as AIS	Secondary (AIS)	Static	Some
AP	All	All	Same as AIS	Predict	Death	Person	Same as AIS	Same as AIS	Secondary	Static	Some
GCS	All	Head injury	All	Predict	Brain damage	Person	Physiological	Real data	Primary	Dynamic	Yes
RTS	All	All	All	Predict	Death and others	Person	Physiological	Real data	Primary	Dynamic	Some
TRISS	All	All	All	Predict	Death and others	Person	Combined	Combined	Secondary (AIS, RTS)	Dynamic	Some
DCP	All	Bone fractures	All	Measure	Damage	Person	Combined	Real data	Secondary (AIS, ISS)	Dynamic	Some
ICISS	All	All	All	Predict	Death	Person[d]	Combined[e]	Real data	Secondary (ICD)	Static	Some
HARM	All	All	All	Predict	Death	Person[d]	Combined[e]	Real data	Secondary (ICD, others)	Static	Little

[a]Length of impairment and time interval until death are not defined uniquely
[b]Limited application to the pediatric population
[c]Very limited physiological description on a handful of injuries
[d]Survival risk ratios are calculated for individual injuries
[e]Categorized as combined because ICD codes include a mix of anatomical and physiological data

Table 14.3 Comparison between the selected injury severity scales across dimensions relevant to their usage

Acronym	Continuous/ categorical	Best summary statistics	Translation into other scales	Scenario	Applications
KABCOU	Categorical	Frequencies	None	At scene	Evaluation and planning
AIS[a]	Ordinal	Frequencies, median, mode	Yes: ISS, NISS	Retrospectively (from medical chart)	Evaluation and planning, biomechanics
ISS[a]	Ordinal	Frequencies of ranges, median	TRISS	Retrospectively (from medical chart)	Evaluation and planning, triage[b]
NISS[a]	Ordinal	Frequencies of ranges, median	TRISS	Retrospectively (from medical chart)	Evaluation and planning
AP	Categorical	Frequencies	None	Retrospectively	Evaluation and planning
GCS[a]	Continuous (3–15)	Means (SD), frequencies	None	At scene	Triage, evaluation and planning, patient monitoring
RTS	Continuous (0–12)	Means (SD)	Yes: TRISS	At scene	Triage, patient monitoring
TRISS	Continuous	Means (SD)	None	At scene	Triage, patient monitoring
DCP	Categorical	Frequencies	None	At scene[c]	Patient monitoring
ICISS	Continuous	Means (SD)	None	Retrospectively	Evaluation and planning, biomechanics[d]
HARM	Continuous	Means (SD)	None	Retrospectively	Evaluation and planning

[a]AIS, ISS, NISS, and GCS scores must be integers
[b]Some trauma centers prioritize treatment to patients exhibiting ISS > 15 (although it is unclear how the score is computed at scene)
[c]As stated by author, however, inclusion of AIS/ISS information increases the feasibility of doing this
[d]As a potential application, the use of ICISS in biomechanics has not been reported to date

Description of Injury Severity Scales and Methodological Implications of Their Use

Traditionally, official figures, for example, on road or occupational injuries, have categorized victims into fatal, serious or slightly injured, or variations on this terminology, including the term "impaired." For example, with regard to motor vehicle injuries, in most countries, the difference between serious and slight injury rests on whether the patient was admitted to the hospital, as reflected in the CARE or IRTAD international databases that collect official statistics on police-reported motor vehicle crashes (ETSC 2001; CARE 2011; IRTAD 2011).

KABCOU is a classification system closely related to the concept described in the previous paragraph (NASS CDS 2009) which classifies injuries into six levels: fatal (K), incapacitating (A), non-incapacitating (B), possible (C), no injury (O), or unknown injury (U). As far back as one can trace the use of injury severity, the desire to know which injuries can cause the death of the patient, which ones require hospital admission, or which ones result in the greatest disability to the subject has been a constant. Yet, there are numerous obstacles to an easy characterization of this concept. Even with an outcome as obvious as death, its use is generally restricted to death that occurs within a specified period after injury, and is therefore susceptible to discussion (e.g., 24 h or 30 days or any time for as long as the primary cause of death in the death certificate is noted to be an external cause (i.e., a V–Z code in the International Classification of Diseases 10th version)). For the remainder of this chapter, we will focus on measures primarily addressing threat to life of the subjects and leave the notions of disability and others for other chapters.

The *Abbreviated Injury Severity* scale (AIS) was developed in 1969 by a joint committee formed by the American Medical Association (AMA), the Society of Automotive Engineers (SAE), and the

Association for the Advancement of the Automotive Medicine (AAAM), which committed themselves to the development of a scale to classify injuries and their severity. The first scale was published in 1971 in the Journal of the AMA (Committee on Medical Aspects of Automotive Safety 1971). The AAAM assumed the lead role for continued development of the scale in 1973. The goal of the new scale was to facilitate the classification of injuries with regard to both anatomic nature of the injury and an estimation of the severity of the injury. Severity was defined for the occasion as a combination of energy required to cause the injury, threat to life, risk of permanent impairment, length of treatment, and injury incidence. The 1985 revision of the scale (AAAM 1985) introduced a numeric system consisting of 7 characters that assigned a unique code number to each injury description contained in the dictionary. The first six digits of the code provide the description of the injury while the seventh and last one (which is separated from the others by a dot) is the assigned AIS severity code that ranges from 1 (minor) to 6 (potentially unsurvivable).

The same format has prevailed intact until the last version of the scale, the 2005 revision (AAAM 2005), which has been recently improved into the AIS 2005 revision 2008 update (AAAM 2008). The 2005 revision offers the possibility of augmenting the code up to a total of 15 digits by using eight optional digits placed after the severity digit. The first four optional digits (called localizers) provide information on the location of the injury (e.g., proximal, distal, bilateral, anterior, superior), and the remaining four serve as descriptors of the intent or circumstances of injury (e.g., intentional vs. nonintentional, child seat forward facing, vehicle-occupant rear seat).

Table 14.4 shows the information that can be extracted from each of the digits of the code.

Without considering the multiplicity introduced by the localizers and descriptors of injury cause, the AIS 2005 revision 2008 update contains approximately 2,000 injury descriptors (four times more than the number published in the first dictionary). The AIS dictionary has been expanded over the years to deal with nonmechanical injuries to parallel the advancement of medical research and to develop comparability with other injury scoring systems. The last revision gives special importance to osseous injuries due to a close collaboration between the AIS Injury Scaling Committee and the Orthopedic Trauma Association (OTA).

For the sake of illustrating the successive changes undergone in the coding of one injury, a fracture of the tibia would have been assigned the code 92401.2 (tibia fracture, not further specified) in the AIS 1985 revision; in the AIS 1990 revision 1998 update, the same injury could have been classified with the code 853404.2 (tibia fracture, any type, without displacement), and the AIS 2005 revision 2008 update would have improved the description of the injury by using the code 854151.2 (proximal tibia fracture, extra-articular).

With regard to the six descriptive digits (predot code), the digit identifying the body region (the first digit) has been commonly used to describe the location of the injury, and therefore, it is common to find injuries classified according to the nine body regions defined in the AIS: head, face, neck, thorax, abdomen, spine (including spinal cord), upper extremities, lower extremities, and not further specified. This same body region classification is used to compute the maximum AIS or MAIS in patients sustaining multiple injuries, as it will be described later in this chapter.

Given the focus of the chapter on the measurement of injury severity, further discussion of the AIS will be limited to the seventh digit of the code. The severity of a given injury is defined by an ordinal scale from 0 to 6, in which 0 means no injury and 6 means maximal severity (virtually unsurvivable) injury. The codes in between these two extremes range from minor to critical severity. A value of 9 can be assigned to the seventh digit in the case of unknown injury severity.

The AIS severity score has been developed by consensus of a group of experts over the life of the AIS. Although threat to life is one of the most important dimensions used by the expert panel to assign the severity score, there are other dimensions that were also considered within the AIS (energy dissipation, impairment, temporary disability, treatment cost). Therefore, the fact that a patient has an injury with an AIS score of 6 does not necessarily mean that he died. Similarly, the fact of the death of the victim does not necessarily mean that the AIS score was 6. Each injury descriptor (predot digits) is associated with a unique severity score. Given the high number of codes and the several

Table 14.4 Interpreting AIS 2005 update 2008 numerical codes by location of digit

1st digit	2nd digit	3rd and 4th digits	5th and 6th digits	7th digit	(8th and 9th digits)	(10th and 11th digits)	(13th through 15th digits)
Body region	Type of anatomical structure	Anatomical structure	Level	Severity	Localizer 1	Localizer 2	Injury cause
1 = Head	1 = Depends on body region (see manual)	Values change by body region (see manual)	In the head, 02 = length of unconsciousness; 04, 06, 08 = level of consciousness; 10 = concussion	1 = Minor	Right, left, middle, bilateral, multiple, upper, lower, and other combinations (see manual)	Fingers/toes, ribs, teeth (see manual)	Intent/type of vehicle/others (see manual)
2 = Face	2 = Vessels			2 = Moderate			
3 = Neck	3 = Nerves			3 = Serious			
4 = Thorax	4 = Organs (including muscles and ligaments)			4 = Severe			
5 = Abdomen and pelvic contents	5 = Skeletal (including joints)			5 = Critical			
6 = Spine	6 = Head—loss of consciousness		In the spine 02 = Cervical 04 = Thoracic 06 = Lumbar	6 = Maximal (currently untreatable)			
7 = Upper extremity							
8 = Lower extremity pelvis, and buttocks							
9 = External and thermal injuries				9 = Not further specified			

(continued)

Table 14.4 (continued)

1st digit	2nd digit	3rd and 4th digits	5th and 6th digits	7th digit	(8th and 9th digits)	(10th and 11th digits)	(13th through 15th digits)
9 = Other trauma	0 = Whole area		In whole area				
			02 = Abrasion				
			04 = Contusion				
			06 = Laceration				
			07 = Avulsion				
			10 = Amputation				
			20 = Burn				
			30 = Crush				
			40 = Degloving				
			50 = Not further specified				
			60 = Penetrating				
			90 = Nonmechanic trauma n				

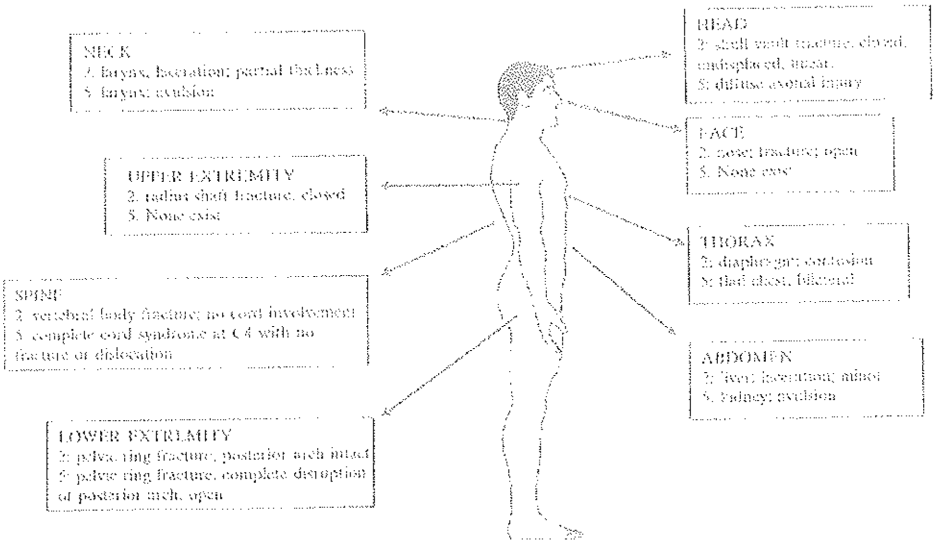

Fig. 14.1 Selected AIS 2005 update 2008, injuries assigned codes of 2 or 5 (in severity) by body region

coding rules that have been developed over the years, training is virtually essential for anyone choosing to use AIS to code injuries.

In the process of assigning the severity scores to specific injuries, the members of the AIS Injury Scaling Committee were asked to make their assessments independent of age and sex of the victim (actually, a few codes were assigned different severity codes if the victim was a child) and to assume the patient would undergo optimal medical treatment. Also, the victims were to be assumed to be perfectly healthy before sustaining the injury. This is of particular relevance since there are other systems that are based on empirically derived severity instead of consensus-based severity as in the case of the AIS. Last, panel members were to focus on the anatomical injury to produce a severity score; only for a handful of injuries is physiological information (e.g., in relation to the duration of the loss of consciousness) used as a modifier to the severity score. Thus, AIS is considered an "anatomical" severity score that remains constant from the time of event onward.

There are numerous studies confirming that the consensus of the experts of the AIS Injury Scaling Committee performs well as a measure of mortality. In an analysis of the correlation between AIS 1990 revision 1998 update and survival using data from the National Trauma Data Bank (NTDB) from patients sustaining a single injury, it was shown that AIS 6 correlates with 80% likelihood of death, AIS 5 with 40%, AIS 4 with 15%, AIS 3 with 3%, AIS 2 with 1%, and AIS 1 with less than 1% probability of death (AAAM 2005).

Figure 14.1 shows an example of several injuries of different severity distributed according to the AIS body regions.

Some suggest that one deficiency of the AIS is that the likelihood of death is different depending on the body region (O'Keefe and Jurkovich 2001). for example, the threat to life of an AIS 5 head injury would be higher than that of an AIS 5 lower-extremity injury. The origin of this criticism can be found in an official document issued by the AIS Committee (Petrucelli et al. 1981), which describes how the ordinal nature of the scale results in some injuries that actually differ in severity being assigned to the same severity category. Another limitation of the AIS is the poor correlation found between the severity scores and the prediction of impairment or length of treatment. Last, the fact of having a single code per each injury poses some difficulties at the time of measuring the injury severity in polytraumatized patients such as the ones typically found in car crashes.

Despite its limitations, the AIS is the injury classification most used in injury prevention research worldwide (and even more so in motor vehicle-related injuries and biomechanics). Numerous information systems have adopted the AIS to classify the injuries resulting from a crash. In the USA, the National Automotive Sampling System Crashworthiness Data System (NASS CDS) slightly modified the conventional AIS (1990 revision), adding an additional code to specify the lateral aspect of the injury. The British Cooperative Crash Investigation Study (CCIS) would be the best example of the use of the AIS in a motor vehicle crash database in Europe. Both the NASS CDS and the CCIS have incorporated the AIS 2005 revision 2008 update in their investigations.

Over the years, the AIS dictionary and manual have been translated into French, German, Italian, Chinese, Spanish, and Japanese. As mentioned earlier, the AIS has also become the standard injury severity measurement used in experimental biomechanics. A vast majority of the biomechanical injury criteria correlate a physical property (e.g., force, acceleration, deflection) with the probability of sustaining an injury of a specific AIS level. The use of the scale is so widespread in the automotive sector that most standards and regulations related to the passive safety of the occupants are expressed in terms of the AIS (US NCAP, FMVSS, ECE regulations, Euro NCAP). For a review of uses of the scale, please see Watchko et al. (under review).

The extensive use of the AIS propitiated the interest of the clinicians in obtaining an algorithm that allowed converting from ICD codes to AIS codes in order to extend its application to larger databases containing ICD information. The first and best known is software called ICDMAP, created to convert ICD-9-MC into AIS 1985 revision (MacKenzie et al. 1989) although it was updated to transform to AIS 1990 revision (Center for Injury Research and Policy of the Johns Hopkins University School of Public Health 1998). Over the years, several other programs to convert between the two systems have been published (Kingma et al. 1994a, b), recently including one allowing the conversion between ICD-10 and AIS 1990 revision (European Center for Injury Prevention 2006). Similarly, the AAAM in its 2005 AIS version provides a conversion algorithm into AIS 1990 update 1998 codes.

The *Maximum AIS* (MAIS) is probably the first attempt of using AIS information to reflect overall injury severity in a patient sustaining multiple injuries. The MAIS (which is simply the highest severity value of any of the considered AIS codes) can be readily assigned for each of the AIS-defined body regions or as an overall score of the patient regardless of the location. However, Baker et al. (1974) found that the overall most severe AIS injury was nonlinearly correlated with death rates and that the severity of injuries in other body regions strongly influenced mortality. These findings resulted in the creation of the Injury Severity Score.

The *Injury Severity Score* (ISS) is the sum of the squares of the three most severe AIS scores in three different body regions (Baker et al. 1974). Six body regions are considered in the case of the ISS: head and neck, face, thorax, abdominal and pelvic organs, extremities and pelvis, and external structures. Like the AIS, the ISS is an ordinal scale (Stevenson et al. 2001a, b) ranging from 0 (no injury) to 75 (if there is at least one AIS 6 code among the three or three AIS 5 codes). The ISS takes the value of 99 in case the severity of any of the injuries is unknown (AIS 9). Some values in the interval (0, 75) are not possible to obtain, such as 7, 15, 23, 28, 31, 37, 39, 40, 44, 46, 47, 49, 52, 53, 55, 56, 58, 60–65, and 67–74.

The *New ISS* (NISS) (Osler et al. 1997) is a variation of the ISS where, instead of using the three most severe AIS codes from three different body regions, one considers the three most severe injuries regardless of their location. NISS is also an ordinal scale ranging between 0 and 75, and, as with the ISS, some values in that interval are not possible. ISS and NISS are well correlated with mortality, which was the main goal behind the development of both systems; several studies have shown that the NISS correlates more closely with mortality than the ISS (Brenneman et al. 1998; Lavoie et al. 2004; Sacco et al. 1999). In addition, the NISS is much simpler to calculate because body regions can be ignored.

The *Anatomic Profile* (AP) is the most recent scale derived from the AIS (Copes et al. 1990). AP also combines AIS codes to produce an alphabetic scale from A to D. Injuries within the A category correspond to AIS 3+ injuries to the head, brain, or spinal cord. AIS 3+ injuries to the thorax or the front of the neck would be classified as B. All other injuries coded as serious (AIS 3) or severe (AIS 4) through maximal (AIS 6) in the remaining body regions would fall into the C category. Facial injuries were placed in D, given the low mortality rate associated with these injuries in the absence of serious brain or head injury. AP was developed with the goal of predicting survival probability and as an alternative to ISS.

The *Glasgow Coma Scale* (GCS) is one of the best known severity scores and the oldest standing injury severity measure based on physiological data only (Teasdale and Jennett 1974). It was also developed during the 1970s and was originally designed to measure the severity of brain injuries with traumatic, vascular, or infectious origin. This scale is also ordinal, and the values range between 3 (deep coma) and 15 (normal). The global score is obtained by adding three individual scores corresponding to motor response, verbal response, and eye response. Despite being widely used, some current prehospital admission practices such as intubation and administration of pain killers can preclude its use.

The *Revised Trauma Score* (RTS) combines information of several physiological parameters such as cardiac frequency, systolic arterial pressure, and breathing frequency of the subject (Champion et al. 1989).

The *Trauma and Injury Severity Score* (TRISS) combines the RTS with information from the injury mechanism (e.g., penetrating yes/no), age, and the ISS to estimate the probability of death.

Borrowing from the concept of "damage control" implemented in the USA to treat penetrating abdominal trauma in the 1980s, Giannoudis (2003) proposed the *Damage Control in Polytrauma* (DCP) which is a severity rating system targeting multiply injured patients sustaining fractures of long bones and/or pelvis (albeit not exclusively). This system aimed to incorporate the notion that inflammatory reaction to the injuries could dramatically alter the outcome of the patients, and it was designed to assist practitioners in deciding on whether and when to intervene. In this system, patients are categorized into being stable, borderline, and unstable in extremis, depending on several anatomical or physiological parameters. For example, for a patient to be labeled borderline, he or she must exhibit at least one of the following: (a) multiple injuries with ISS > 20 including a thoracic injury AIS > 2, (b) multiple injuries with abdominal/pelvic trauma and initial systolic blood pressures <90 mmHg, (c) ISS > 40, (d) radiographic evidence of bilateral pulmonary contusion, (e) initial mean pulmonary arterial pressure [illegible] mmHg, or (f) pulmonary artery pressure increase during intramedullary nailing >6 mmHg.

Because of the amount of clinical information that is needed to use any of the above four measures (GCS, RTS, TRISS, or DCP), they are not as frequently used as those based on an anatomical description. Further, all these measures that use physiological parameters have to incorporate the fact that physiological conditions change in time. Therefore, comparison between different scores would make sense only if the time since injury is also prescribed (and comparable between the systems).

The *International Classification of Injury Severity Score* (ICISS) derived *Survival Risk Ratios* (SRRs) for every ICD-9 injury category using the North Carolina Hospital Discharge Registry (Osler et al. 1996). These SRRs are calculated as the ratio of the number of times of a given ICD-9 code occurs in a surviving patient to the total number of occurrences of that code. The ICISS is defined as the product of all the survival risk ratios for each of an individual patient's injuries (for as many as ten different injuries) (Osler et al. 1996). Thus, the survival risk for a given subject decreases if either there is an injury with a very low associated survival risk or there are multiple injuries even if their survival risks are moderate. Table 14.5 shows a selection of ICD-9-CM codes with the highest mortality risk as derived by the ICISS.

Although over the years other parameters have been considered for addition to ICISS (such as age, injury mechanism, or even the RTS), the ICISS remains as an injury measurement based on the ICD description of the injuries.

Table 14.5 Random selection of 10 out of 100 ICD 9 MC codes with the lowest SRRs presented, sorted from lowest to highest SRR value (source: Osler et al. 1996)

SRR	ICD-9-CM	Description
0	852.35	Subdural hemorrhage, continuing LOC
0.41	902.33	Portal vein injury
0.51	902.0	Abdominal aorta injury
0.53	901.2	Superior vena cava injury
0.64	850 4	Concussion, continuing LOC
0.68	902.53	Iliac artery injury
0.72	958.4	Traumatic shock
0.74	902.31	Superior mesenteric vein injury
0.79	806.04	Cervical fracture, C1–C4
0.79	902.42	Renal vein injury

The *Harborview Assessment for Risk of Mortality Score* (HARM) (Al West et al. 2000) groups the ICD-9-CM codes into 109 categories and also incorporates information on the injury mechanism (e.g., traffic crash, fall), intentional vs. unintentional causes, preexisting medical conditions, and age and gender of the subject. HARM can also handle multiple injuries in one subject. All the information needed to use HARM is generally available in hospital admission databases. A comparison between the survival risk associated with ICISS and the different ICD-9 codes in HARM reveals a great similarity between both systems. The ten most severe injuries in HARM would be those that most increase the risk of death. Thus, the most lethal injury according to HARM is loss of consciousness for more than 24 h (95% increase in mortality risk), followed by full-thickness cardiac lacerations (67% increase) and unspecified cardiac injuries (32%), and next, complete spinal cord injury at the level of C4 or above (31% increase of the risk of death), injuries to the superior vena cava or innominate vein (28%), pulmonary laceration (27%), cardiac contusion (22%), traumatic amputation above the knee (21%), major laceration of the liver (15%), and injuries to the thoracic aorta or great vessels (14%). The reader is reminded that these estimations of risk are adjusted by sex and gender, injury mechanism, and all other aforementioned variables involved in HARM. It is relevant to note here that this measure is not to be confused with HARM as defined by the US National Highway Traffic Safety Administration, which is a metric to value cost of injuries (Miller et al. 1995).

In fact, the two last measures are efforts to provide a severity score, as with the AIS. However, the methods used within each of the systems to derive the mortality risk estimations from empirical data can be also questionable. For instance, both ICISS and HARM make use of hospital data, and therefore, mortality is frequently calculated at discharge ignoring all deaths prior to hospitalization, which in some instances can amount to more than 50% of the deaths. On a more general note, the transferability to other circumstances and locations of these systems (that have been developed based on information of specific regions and hospitals within the USA) must be assessed. ICISS is being more commonly used than HARM in the literature.

Challenges for Future Development

As stated in Chawda et al. (2004), "the plethora of available scoring systems for trauma [severity] suggests that there is a need for a universally applicable system, but this goal may be difficult to achieve." Part of this difficulty may relate to the fact that the concept of severity is somewhat ill-defined. Since the 1960s, short-term survivability seems to be at the heart of most developed metrics, yet other concepts, such as difficulty of treatment and likelihood of long-term impairment, have cluttered its operational definition. Out of a plethora, this chapter presents a selection of measures that apply to most populations, injuries, and injury mechanisms and that are widely found in the literature. Even these lack definitional precision of the term "severity." Of the scales presented here, only the AIS, the ISS, and the RTS (in its first version, called Trauma Score) were included in the 1984 review by MacKenzie (1984).

As with any other health measure, severity scores should be subjected to rigorous evaluation for validity and reproducibility. Validity can only be measured if the outcome under evaluation is clearly defined. For example, how and whether to combine AIS scores into any mathematical model to derive patient-based severity scores can only be determined if, for example, predicting death, is set as the objective. In this regard, definitional issues need to be addressed across all measures, and whether their validity differs depending on the subpopulation must also be considered. For example, whether the pediatric-related modification of a few AIS scores in the 2005 version is sufficient to adjust the validity of the measure in this subpopulation needs to be investigated.

Regarding reliability, since the mid-1980s, there is a call for the rigorous application of scoring criteria (MacKenzie 1984). In the case of the AIS, its parent organization (AAAM) has developed an extensive in-person and online training program around the world (www.aaam.org). However, the number of users trained to code AIS or most other scales remains low, as revealed when publications indicate misuse or misunderstanding of the codes (Watchko et al. under review).

When scores range between several values and decisions to transfer and/or treat patients are made based on those scores, rigorous analysis of specificity and sensitivity, including development of receiver operating characteristic (ROC) curves, is due. Due to the insufficient research on these topics for most of the scales, more work is needed, particularly in the triage and decision-making application of these measures.

These measures also vary in the mathematical nature of the numbers produced; some are categorical variables, others, ordinal, yet others, continuous. Often, they are all used as continuous variables, resulting in inappropriate arithmetical operations and statistical analysis. Users need to be mindful of the actual analytical possibilities of the measures.

Since the objectives are severalfold, it is likely that no scale serves best for all purposes, particularly in triage and clinical applications. Yet, when it comes to evaluation and planning or biomechanical applications, the AIS, SRRs, and injury-specific HARM scores, as well as their composites to address overall severity, are being widely used and in somewhat of a competition. Some researchers argue against the consensus-derived AIS as assessed by experts who belong to the AIS Committee. Some even produced real-world probability-of-death ratios for the predot AIS codes of motor vehicle injury victims collected under the US National Highway Traffic Safety Administration National Automotive Sampling System Crashworthiness Dataset (Martin and Eppinger 2003). Nevertheless, the fact is that real-world probability-based measures such as ICISS or HARM are not exempted from criticism. For example, which data to use and where to apply become crucial. For example, are SRRs derived from hospital discharges in the 1990s in North Carolina applicable to 2010 hospitalized injury patients in Spain? Time- and space-external validity becomes an important parameter to assess.

In the years ahead, it is possible that redefinition and refinement of the concept of injury severity will allow for further development of existing or newly developed scales. At the population level, and in regard to program evaluation purposes, severity measures derived from already collected data will continue to prevail both as outcome variables and as independent variables (and possible confounders) in multivariate analyses. It will be interesting to see whether the field will be dominated by SRRs (and derivatives) or the AIS (or derivatives) computed using algorithms based on ICD

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