Measuring Injury Severity

A brief introduction

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Injury severity is an integral component in injury research and injury control. This lecture introduces the concept of injury severity and its use and importance in injury epidemiology. Upon completing the lecture, the reader should be able to:

1. Describe the importance of measuring injury severity for injury control
2. Describe the various measures of injury severity

This lecture combines the work of several injury professionals. Much of the material arises from a seminar given by Ellen MacKenzie at the University of Pittsburgh, as well as reference works, such as that by O'Keefe.

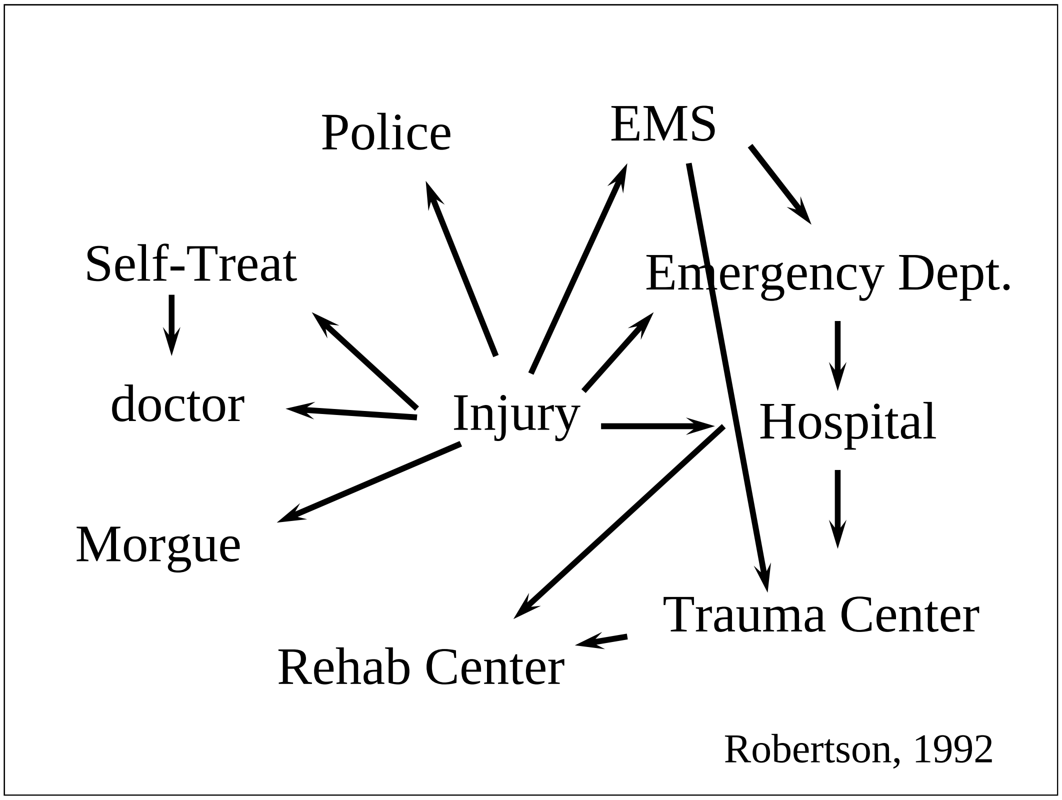
Further details are available at:

"Measuring Injury Severity" by Ellen MacKenzie. Online at:

http://www.circl.pitt.edu/home/Multimedia/Seminar2000/Mackenzie/Mackenzie.htm

O'Keefe G, Jurkovich GJ. Measurement of Injury Severity and Co-Morbidity. In Injury Control. Rivara FP, Cummings P, Koepsell TD, Grossman DC, Maier RV (eds). Cambridge University Press, 2001.

Material in the lectures before have spoken of the injury pyramid. It illustrates that injuries of differing levels of severity occur at different numerical frequencies. The most severe injuries occur less frequently. This point raises the issue of how do you compare injury circumstances in populations, particularly when levels of severity may differ between the populations.



For this issue, consider that injuries are often identified from several different sources. These sources are likely to capture events of differing severity between them, and also within them. Hospital admissions, for example, may include injuries of maximal severity requiring intensive care and those of lower levels of severity that involve an overnight observation period.

Major Areas of Application on Injury Severity Indices

- ❖ Triage
- ❖ Prognostic Evaluation
- ❖ Research and Evaluation

Injury severity scales are used in three primary applications. These include triage applications to set priorities for patient treatment, prognostic evaluations to predict or manage injury outcomes, and research applications to compare groups on injury outcomes or treatment effects.

Is there potential for improvement in the care of injured patients?

As an example, consider the question posed here; can we improve the care of injured patients? The obvious answer is to say yes! There are studies and anecdotal reports that indicate that not all trauma care is optimal, and that patterns of care differ by institution or geographic region of the country.

However, to begin the process of answering this question, a researcher must define trauma care, but also who is receiving trauma care. Injury severity scales fit into the picture here by providing a structure to classify patients based upon the severity of their injuries.

Improvements in outcomes related to injury may be achieved by:

- Enhancing pre-hospital care
- Adopting ATLS principles
- Integrating trauma care within and between hospitals
- Investing in rehabilitation services

Improving care to enhance injury outcomes can take many forms, such as those outlined here. Pre-hospital, or emergency medical services (paramedics) can be improved. This may involve training or guidelines on the transfer of patients to the most appropriate facility. The principles of ATLS (Advanced Trauma Life Support) may also be adopted.

Other examples that may improve care would include the integration of trauma care services within and between hospitals, and the development of a plan to enhance the use of these services. Long-term care provision may also improve injury outcomes with respect to the quality of life of the person injured.

Studies to evaluate the success of these interventions to improve injury outcomes will require comparisons between groups. Injury severity can be an important confounding variable in such an evaluation. Thus, adjustment for injury severity is central to the assessment of treatment interventions for injuries.

Measuring the Burden of Injuries

- Fatal
  - Counts and rates
  - Years of Potential Life Lost
- Non-fatal
  - Short term
    - Health care use
      - Hospitalization rates
    - Functional limitations
    - Severity
      - AIS
      - RTS, etc
    - Pathology

Segui-Gomez

Injury severity scales may also be used to characterize the burden of injury in descriptive studies. This slide illustrates that injury severity is one of a number of measures on the significance of non-fatal injury.

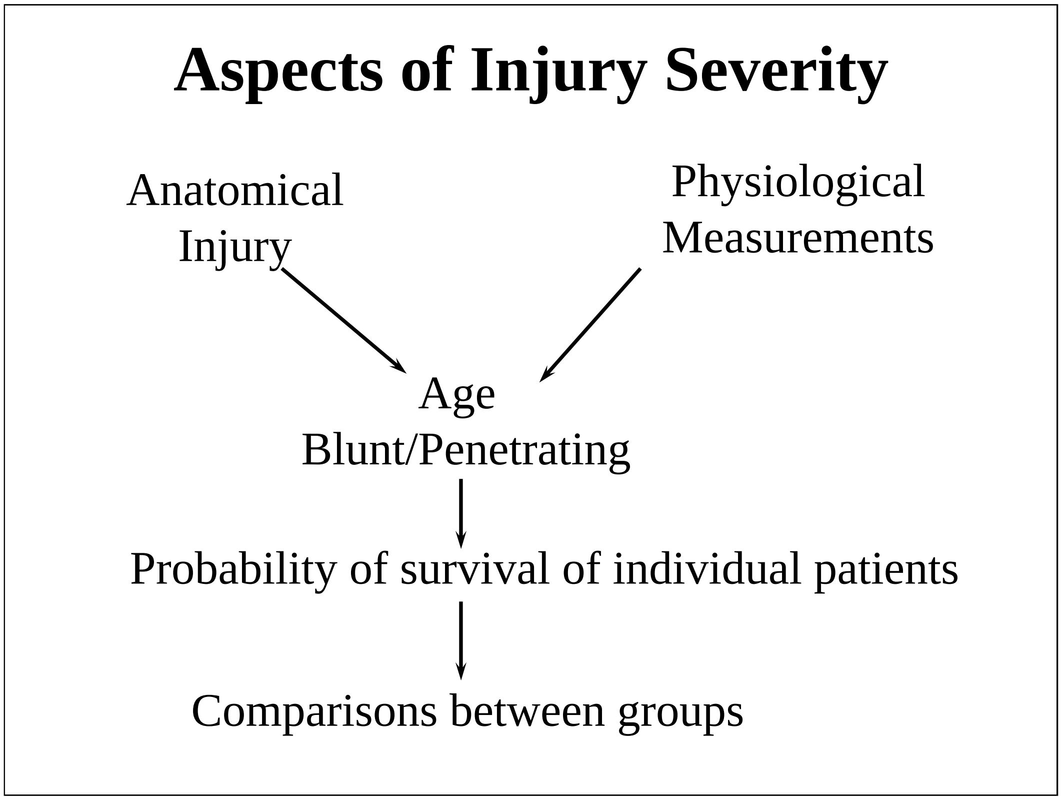
Injury Severity Scales

How do you measure and score injury severity? The remainder of the lecture will overview several scales that have been developed to quantify injury severity.

Impact of the Injury will depend on...

- ❖ Extent of tissue damage
- ❖ Physiological response to the injury
- ❖ Host factors that mediate the response

The development of injury severity scales has been influenced by three factors. The first two factors are the basis for the majority of the existing scales; (a) the area of the injury and its nature of damage, and (b) the physiologic state of the body in response to the injury. The third issue, host factors, has recently been recognized as potential variables that mediate injury outcome, and attempts are now underway to consider them in the assessment of injury severity. More details follow….



While anatomy, physiology, and host factors may influence the manner in which injury severity is assessed, these variables do not occur in a vacuum. This slides illustrates a model which is meant to emphasise that these variables ultimately work together to determine the outcome of a patient following an injury. Thus, they are all important in assessing injury severity.

However, several of the injury severity scales are based only on one aspect of this model. For example, the anatomical injury aspect. These one dimensional scales have been criticised on this basis.

INJURY SEVERITY

Alphabet Soup

Several injury severity scales exist in practice and in the literature. They represent, literally, an alphabet soup of assessment. The sheer number of scales arises from the markedly different perspectives used in the application of the scales. Preferences for certain scales exist among differing disciplines. The assessment of motor vehicle injuries, for example, relied mainly on the AIS (Abbreviated Injury Scale) for several years. The assessment of trauma relies today on the GCS (Glasgow Coma Scale). But other scales have been developed to supplement and overcome the limitations of these two primary scales.

Abbreviated Injury Scale (AIS)

- ❖ Anatomical measure that addresses the extent of tissue damage
- ❖ ICD-based classifications

The Abbreviated Injury Scale (AIS) is the first widely implemented injury severity scale used in practice. It was developed in 1971 for use in assessing motor vehicle injuries. The efforts of Haddon and colleagues at the NHTSA recognized the need for a standard measure of injury severity in the studies of injuries related to automobiles. Determining if the type of injury (e.g. head trauma) differed by model of vehicle in similar types of crashes was dependent upon a standard to scale the severity of the head trauma. The AIS met this need.

The AIS is primarily an anatomical measure of injury severity. It classifies severity on the basis of the body region injured and the magnitude of the injury in that body region. The AIS is still used today in practice, and has the advantage of having a direct link to ICD 9 CM classifications of injury. It is used now to examine all types of injuries, not just motor vehicle injuries.

AIS Severity Component

1 MINOR
2 MODERATE
3 SERIOUS
4 SEVERE
5 CRITICAL
6 MAXIMUM INJURY, VIRTUALLY UNSURVIVABLE

The AIS codes the primary injury in a body region over a scale of 1 to 6. This slide illustrates the level of severity assigned to each number. A higher severity score indicates a progressively more severe injury (O'Keefe). An AIS score of 1 translates to a minor injury, while an AIS score of 6 is deemed an unsurvivable injury. It is important to note that the scores from 1 to 6 do not reflect an interval scale, and similar AIS scores may not be comparable across body regions. For example, an AIS 3 score for head trauma may reflect an injury of different severity than an AIS 3 score for another body region, such as the extremities (O'Keefe).

Severity scores are subjective assessments assigned by experts

Implicitly based on four criteria:

- ❖ Threat to life
- ❖ Permanent Impairment
- ❖ Treatment Period
- ❖ Energy Dissipation

The severity scores from 1-6 in the AIS were determined by the subjective assessment of a group of experts. They used the four criteria outlined in this assessment. Injuries with greater magnitude of these criteria were weighted to reflect greater severity.

Addressing Multiple Injuries

for predicting survival

- Injury Severity Score (ISS)
- The New Injury Severity Score (NISS)
- The Anatomic Profile (AP)

The main criticisms of the AIS include the inability of this scale to take into account multiple injuries in the same body region and the poor correlation with AIS severity and survival (O'Keefe). As a result, several scoring systems have been developed to overcome these shortcomings. These systems include the Injury Severity Score (ISS), the New Injury Severity Score (NISS), and the Anatomic Profile (AP).

The ISS uses much of the same framework of the AIS, but it attempts to quantify the impact of multiple injuries on mortality. For example, it assesses the anatomical site of the injury and assigns an AIS severity score using the AIS system. However, it differs by deriving a summary score on the basis of the 3 most severely injured body regions. No single region can be represented more than once in the score (O'Keefe).

The sum of the squares of the severity score in these 3 regions is then used to determine the ISS score. This process, summing of the squares, provides a greater approximation to mortality prediction, and this is the rationale for using this approach (Baker, 1974)

See: Baker SP, O'Neill B, Haddon W, Long WB. The Injury Severity Score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 14:187-96, 1974.

INJURY SEVERITY SCORE
Example

	AIS Score
Small subdural haematoma	4
Parietal lobe swelling	3
Major liver laceration	4
Upper tibial fracture (displaced)	3

$$ISS = 4^2 + 4^2 + 3^2 = 41$$

This slide provides an example of the ISS scoring process. The individual has significant injuries in three regions; the head, the abdominal region, and an extremity (lower leg). The three most severe scores (subdural hematoma in the head region) in each body region are applied, by rule. The ISS score adds to 41.

In general, ISS scores have a range of 1 - 75. A score of 1 represents a minor injury, a score of 75 represents a fatal injury. By definition, any AIS body region score of 6 results automatically in an ISS of 75. An ISS score of 1 is possible if only one body region is injured.

Criticisms of the ISS

- Does not take into account multiple injuries within a body system
- Equal weights across body regions; underscores severe head injuries

Several criticisms of the ISS exist. As the ISS is largely based upon the AIS severity scoring system, it has some of the same limitations. For example, the severity scores (AIS 1-6) are based upon subjective expert opinion. Again, the ISS also does not consider the impact of multiple injuries within one body region in its assessment, and it considers the severity score in the head region to be similar to other body regions.

The *New* Injury Severity Score (NISS)

Sums of squares of the 3 highest AIS scores *regardless of body region*

A revision of the ISS has been developed to address the issue of multiple injuries in the same body region. The New Injury Severity Score (NISS) is very similar to the ISS. However, it scores the three most severe AIS scores regardless of their body region location. Thus, multiple injuries within a body region can be considered in the NISS.

See: Baker SP. Advances and adventures in injury prevention. J Trauma: Injury Infect Crit Care 42:369-73, 1997.

ISS vs. NISS - an Example

	AIS Score	*Region*
Multiple abrasions	*1*	External
Deep laceration tongue	*2*	Face
Subarachnoid hemorrhage	*3*	Head/Neck
Major kidney laceration	*4*	Abdomen
Major liver laceration	*4*	Abdomen

ISS $= (4)^2 + (3)^2 + (2)^2 = 29$

NISS $= (4)^2 + (4)^2 + (3)^2 = 41$

In this example, an individual has 5 significant injuries. The NISS differs from the ISS in that it includes both injuries in the abdomen (liver and kidney lacerations) because their levels of severity exceed those of the injuries in the other regions.

Anatomic Profile

The Anatomic Profile (AP) is another severity scoring system. It was developed to address the shortcomings of the ISS and to increase the precision involved in scoring multiple injuries (O'Keefe).

Anatomic Profile
Definition of Components

Component	AIS Region	AIS Severity
A	Head/Brain	3-6
	Spinal cord	3-6
B	Thorax	3-6
	Front of Neck	3-6
C	All other body regions	3-6
D	All others	1-2

The square root of the sum of squares of AIS scores is used to summarize a component's injuries

The Anatomic Profile also uses the AIS severity scores in its measure. It differs from the ISS (and is similar to the NISS) by including multiple injuries within one body region (O'Keefe). The AP score is made up of four components (labeled A through D). Components A, B, and C represent serious injuries; injuries with AIS scores of 3 or greater. The slide illustrates this concept with the body regions assigned to each component. Four specific body regions were chosen (head/brain, spinal cord, thorax, and neck).

The score for each component is derived by taking the square root of the sum of squares of all AIS scores in the body region in that component. This enables multiple injuries within a region to be recognized. The sum of the values for a four components constitute the AP score.

The AP system is not widely used in injury severity scoring.

ICD to AIS Conversion (ICDMAP)

- ❖ Converts ICD-9CM coded discharge diagnoses into AIS scores and computes ISS, NISS, APS
- ❖ Conservative measure of injury severity - refer to as *ICD/AIS* scores

Despite their limitations, the AIS and ISS scales still receive wide use. This is due in part to the effort established in the 1985 revision to AIS to link ICD-9-CM codes with AIS codes. A conversion table which relates specific ICD codes to AIS codes was added in this revision. Subsequently, it is possible to derive ISS and NISS scores from ICD-9-CM Codes. A computer program, ICDMAP, allows this process to be automated with existing medical datasets.

It is important, though, to recognize the conservative nature in which ICD codes are converted to AIS scores. ICD diagnosis codes do not, in all situations, correlate well with the AIS injury classification (O'Keefe). Assumptions have been made in the conversion table to best approximate the AIS score. However, it is possible that a review of the medical record may lead to a different AIS score. Also, some large datasets may not have a large number of diagnosis fields within them to allow one to capture multiple injuries within body regions.

See: MacKenzie EJ, Steinwachs DM, Shankar B. Classifying trauma severity based on hospital discharge diagnosis. Validation of an ICD-9-CM to AIS-85 conversion table. Medical Care 27:412-22, 1989.

Injury Severity Scales

In Use

As mentioned previously, injury severity scales has multiple uses. The largest area of their application, though, lies in trauma scoring systems, and identifying the role of trauma care in the treatment of the injured patient.

Evaluating System Performance

- Using hospital discharge data, classify patients according to where they should have been treated (based on AIS severity)

- Compare where they should have been treated to where they actually were treated

Here is one example of the use of injury severity in an analysis of health system performance for injured individuals. Before the development of the ICDMAP software, there was limited ability to examine whether people who needed trauma centers on the basis of the severity of their injuries actually GOT to a trauma center.

This is because the only information we had available to us was from the trauma centers themselves. Information on those who did not get to a trauma center was contained in medical databases that did not identify injury severity. Now, with the increasing availability of statewide hospital discharge data and the ability to translate ICD codes into AIS severity scores , we can classify ALL injured patients according where they should have been treated – based on the severity of their injuries – with where they actually ended up – thus providing one measure of system performance .

Information Source: MacKenzie seminar

Percent of ISS > = 16 Patients Getting to Trauma Centers:

Metro Area A	**55%**
Metro Area B	**59%**
Metro Area C	**66%**
Metro Area D	**68%**
Metro Area E	**73%**
Metro Area F	**78%**
Metro Area G	**85%**

Ellen MacKenzie did this for seven different metropolitan areas around the country – ALL of whice claimed to support a regional trauma system.

As presented, however, the percent of major trauma patients who actually end up in trauma centers varies quite substantially across these areas.

Several trauma systems around country are now using ICDMAP software as part of their ongoing evaluations and benchmarking their performance against other regions of similar size and characteristics

Information source: MacKenzie seminar

Physiologic Response

- ❖ Glasgow Coma Score
- ❖ Revised Trauma Score

The discussion of injury severity to this point has focused on scales that have scoring systems based on anatomy. A second set of injury severity scales exist which are based upon the physiologic result of injury rather than the anatomic result. Physiologic measures have the advantage of assessing indicators (such as heart rate, blood pressure, respiratory rate) that more closely reflect the effects of an injury and its severity. However, these indicators also change over time. When tracking the status of an individual patient, this is no big deal. When tracking severity of populations of patients, though, it becomes more important, as debate exists over which value of the indicator to record for comparison across groups.

Two widely used scales in this domain are the Glasgow Coma Score (GCS) and the Revised Trauma Score (RTS).

Glasgow Coma Scale

- Head injuries vary as to severity ranging from mild, moderate, to severe
- The Glasgow Coma Scale is a measure of this severity
- The GCS is assessed immediately following the injury and during the initial recovery

The Glasgow Coma Scale was another one of the first scoring systems used. Devised in 1974, it focuses on the importance of central nervous system function and is used widely as a triage and prognostic indicator.

Glasgow Coma Scale

Parameter	Response	Score
Eye opening	Nil	1
	To pain	2
	To speech	3
	Spontaneously	4
Motor response	Nil	1
	Extensor	2
	Flexor	3
	Withdrawal	4
	Localising	5
	Obeys command	6
Verbal response	Nil	1
	Groans	2
	Words	3
	Confused	4
	Orientated	5

The GCS is based upon the first observation after injury on three functions; verbal response, motor response, and eye-opening. Each function is scored on the scale noted in this slide. The total GCS score is determined by adding the scores on each function. GCS scores range from 3-15 (severe to less severe).

Although it is widely applied, there are notable limitations in the GCS. For example, verbal response scores may not be available for someone who in intubated. The GCS score also has problems if used in population outcome prediction (O'Keefe).

Revised Trauma Score

- a physiological measurement
- based on data at arrival to hospital

considers:

Respiratory rate

Systolic blood pressure

Glasgow Coma Scale

A second physiologic measure is the Revised Trauma Score (RTS). It is the most widely used physiologic measure. The RTS is not limited to patients with brain trauma or central nervous system involvement. The RTS provides a scored assessment of the physiology of the individual based upon the values in three indicators; respiratory rate, blood pressure, and the GCS. By definition, the RTS on arrival at the hospital is the one value documented into record systems.

The RTS is often used for triage decisions, whether in the field by paramedics or in the emergency department. It may also be used for assessing prognosis if the RTS on arrival is compared to the best RTS after resuscitation.

Revised Trauma Score

Clinical Parameter	Category	Score	x weight
Respiratory rate (Breaths per minute)	10-29	4	0.2908
	>29	3	
	6-9	2	
	1-5	1	
	0	0	
Systolic blood Pressure	>89	4	0.7326
	76-89	3	
	50-75	2	
	1-49	1	
	0	0	
Glasgow Coma Scale	13-15	4	0.9368
	9-12	3	
	6-8	2	
	4-5	1	
	3	0	

The clinical parameters in the RTS are scored much like in the GCS. Values may range from 0 to 12 (most affected to least affected). Some health care systems use the RTS to determine which patients go to Level 1 or Level 2 trauma centers.

When used for outcome analysis (non-triage uses), the scores in each clinical category (respiratory rate, blood pressure, GCS) of the RTS are weighted. These values provide more accurate assessments of outcome than the unweighted RTS. The weights are based upon outcome data from the MTOS (Major Trauma Outcome Study).

Assessing RTS may be problematic

Accurate GCS and RR difficult when the patient is intubated, chemically paralyzed or under the influence of drugs or alcohol

Limitations exist in the RTS. As noted in the GCS, intubation may affect the assessment of verbal response, as well as the assessment of the respiratory rate. The influence of alcohol may also affect these scores.

Possible solutions have been proposed to these issues. They include estimating verbal response based upon the eye-opening score and the best motor response in the GCS, or alternatively, using pulse rate or systolic blood pressure values alone.

Host Factors

- Age
- Pre-existing conditions
- Other

Several host factors may influence or confound the results of injury severity scales. The primary factors of interest include age and co-morbidity. Despite similar injury severity scores, the prognosis for recovery may differ by significantly by age, with older individuals faring worse than younger individuals.

The presence of pre-existing medical conditions can be quite common in trauma patients. About 20% of all hospitalized trauma patients have one or more pre-existing conditions (MacKenzie seminar). This pattern will likely increase in the future as obesity and the conditions related to obesity increase in the population.

Combining information on …

Tissue damage

Physiologic response

Host factors

Today, strong sentiment exists to build injury severity scales that combine the severity of anatomic injury with the acute physiology of injury and consider the confounding influences of age and other host factors.

Probability of Survival Models

- TRISS
- ASCOT

By combining anatomic and physiologic measures and age, it has been possible to model survival probability following trauma (O'Keefe). Two methods predominate in this realm; the Trauma and Injury Severity Score (TRISS) and A Severity Characterization of Trauma (ASCOT) measure.

TRISS assesses the probability of survival based upon the RTS, mechanism of injury (blunt/penetrating), age, and ISS (O'Keefe). ASCOT considers the RTS, mechanism of injury, age, and AP score in its assessment.

Further Improvements

Refining the State of the Art

1. Further refine the AIS and RTS
2. Revisit Probability of Survival Models -- especially for population based data
3. Better delineate role of host factors

Room for further improvement lies in the assessment of injury severity across groups. Improvement may follow several paths that focus on improving the basic measures (AIS, RTS) themselves, building better survival probability models, and enhancing the measurement of host factors.

AIS BASED MEASURES of IMPAIRMENT

- Injury Impairment Scale (IIS)
- Functional Capacity Score (FCI)

One area of improvement that is receiving needed attention is a new focus on non-fatal injury outcome assessments. The fundamental aspect of the most widely used injury severity scales is that they are based on their ability to predict mortality. This perspective ignores non-fatal injury and the resultant disability that may arise. Two new measures; the Injury Impairment Scale (IIS) and the Functional Capacity Score (FCI) seek to enhance our knowledge in the area of non-fatal injury outcomes. Look for these measures to receive more attention in the near future.