Injury Epidemiology: Fourth Edition

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Chapter 4. INJURY SEVERITY

The measurement of injury severity is an essential element of the use of injury epidemiology for injury control. In any given year, virtually everyone experiences minor injuries, such as small scratches, bruises, and burns. Most of these heal with little or no treatment and do not interfere with one's activities. The energy sources, vehicles and vectors, and other circumstances of injuries, are usually not the same for those that are relatively severe and those with trivial consequences. Since trivial injuries are so common, priority in the devotion of resources to control of injuries based on total numbers in a given category can result in substantial misallocation of resources concerning the improvement of the quality of life of the severely injured or their families and reducing the cost of injuries.

The measurement of injury severity is based on numerous clinical signs and symptoms such as respiration rate, consciousness, blood pressure, heart rate, number and types of organ and system damage such as area and depths of burn, ruptured spleen, and site-specified damage to the spinal cord. Researchers have developed summary scores of these factors that are meaningful in terms of decisions related to severity reduction, acute care, and rehabilitation. Several competing scoring systems have been developed and no single one is likely to emerge that would be acceptable to everyone for the variety of potential uses.

SEVERITY SCORES. Severity scores are used in acute and follow-up medical care to triage patients (decide where and by whom patients should be treated), to plan for the different levels of care needed according to severity distributions, and to evaluate the effectiveness of treatment. Epidemiologists use severity scores to establish minimum criteria for surveillance of injury, to measure the effects of energy and other factors on injury severity (including the effects of attempts at injury control), and to estimate injury effects on mortality, disability, and costs (Baker, 1983).

The elements of one severity scoring system, the Trauma Score, includes respiration rate, systolic blood pressure, Glasgow Coma Score, verbal response, and motor response (Champion, et al., 1981). The signs and symptoms in this system are widely used by emergency medical personnel for triage and by

emergency care physicians for the initial evaluation of patients, such that records for use in research are often available. The originators of the score have revised it and the revision (Champion, et al., 1989) is occasionally used in research on trauma care but seldom by injury epidemiologists.

Examples from another severity rating system, the Abbreviated Injury Scale (AIS), are shown in Table 4-1. It is based on a dictionary constructed from the expert judgment of the severity of particular injuries (Committee on Injury Scaling, 1980). The AIS is seldom used for triage, but it is used in epidemiologic studies as well as the evaluation of medical care outcomes and costs. The scoring procedure has been simplified into a standardized instrument that can be used in case of abstraction from medical records (Barancik and Chatterjee, 1981) or to convert International Classification of Diseases (ICD) diagnosis codes to AIS scores (Durbin, et al., 2001). Also, a comparison of AIS scores from hospital record reviews and those obtained using a computer program to compute AIS scores from computerized hospital discharge records found agreement in 48 to 75 percent of cases depending on the type of injury (MacKenzie, et al., 1989; 1997).

Table 4-1. The Abbreviated Injury Scale (AIS), With Examples

Code	Descriptor	Examples
0	No injury	Minor superficial abrasion or laceration of skin; digit sprain; first-degree burn; head trauma with headache or dizziness but no other neurological signs
2	Moderate	Major abrasion or laceration of skin; unconscious but <15 minutes; finger or toe crush/amputation; closed pelvic fracture
3	Serious	Major nerve laceration; multiple rib fracture without flail chest; abdominal organ contusion; hand, foot, or arm crush/amputation
4	Severe	Ruptured spleen; leg crush; chest-wall perforation; unconscious <24 hours
5	Critical	Spinal cord transection; extensive/deep laceration of kidney or liver; extensive second- or third- degree burns; unconscious 24+ hours
6	Unsurvivable	Decapitation; torso transection

A derivative of the AIS is the Injury Severity Score (ISS) – the sum of the squared AIS in each of the three most severely injured of seven defined regions of the anatomy. These regions are the head, neck, thorax, abdomen and pelvic contents, spine, extremities and bony pelvis, and external skin and muscles. The ISS was developed by researchers concerned with refining the prediction of fatal injury, particularly in the case of multiple traumas (Baker, et al., 1974). The score was subsequently modified to use the second and third most severe injuries even if they occurred in the same region of the anatomy (Osler, et al. 1997). The researchers noted that the probability of survival in a series of hospitalized trauma patients increased exponentially as a function of the AIS scores. Cross-tabulation of the three most severe injuries indicated that the square of these AIS scores was

a strong predictor of the probability of survival, particularly when corrected for the age of the injured.

These scoring systems are attempts to quantify a mixture of quantitative and qualitative elements of the extent of an injury. The quantitative elements of the Trauma Score, such as respiration rate and blood pressure, are given a low (adverse) score when higher or lower than normal. Although each of these measurements could be used quantitatively without categorization in segments, mathematical modeling of them in combination to obtain a useful score would be very complex, and difficult to use in emergencies without an especially designed calculator with logic built into it. An online calculator of the injury severity score is available at https://www.mdcalc.com/injury-severity-score-iss. An index combining the Trauma Score and the Injury Severity Score (TRISS), as well as patient age, has been developed using logistic regression, with the probability of survival as the outcome (Boyd, et al., 1987). Logistic regression is a technique that assigns weights to different factors regarding their relative power to predict the probability of a discrete outcome such as death versus survival (e.g., Selvin, 1991). Cases in which the patient dies despite a high probability of survival, or survives despite a low probability of survival, are suggested as worthy of peer review by the American College of Surgeons (Committee on Trauma of the American College of Surgeons, 1987). The validity of this approach has been verified for children's injuries as well (Kaufmann, et al., 1991). Modifications of the measurements improve the prediction of death from penetrating injuries (Champion, et al., 1990). An online calculator for TRISS scores is available at https://www.thecalculator.co/health/Trauma-Injury-Severity-Score-(TRISS)-Calculator-1022.html.

Since the ISS leaves out some injuries, a system called the Anatomic Profile was developed to summarize the AIS of all injuries. A committee of clinical experts defined sets of injuries to comprise components of a score. The square root of the sum of the squares of the AIS of each injury in each component was related to the probability of survival obtained by logistic regression. A comparison of the Anatomic Profile (AP) scores and ISS scores indicated an improvement in the prediction of survival by using the AP (Copes, et al., 1990). The score is the sum of the points for each component.

Physicians who treat trauma in children have been critical of the use of indices based on the measurement of trauma and outcomes for adult patients. A Pediatric Trauma Score, the elements of which are shown in Table 4-2, has been shown to have an excellent correlation to the probability of survival of traumatized children (Tepas, 1989).

A variety of other trauma scoring systems has been studied concerning outcomes other than death -- the Mangled Extremity Severity Score; the Limb Salvage Index; the Predictive Salvage Index; the Nerve Injury, Ischemia, Soft-Tissue Injury, Skeletal Injury, Shock, and Age of Patient Score; and the Hannover Fracture Scale-

98. None was useful in the decision to amputate a severely injured lower extremity (Thuan, et al., 2008).

Table 4-2. Pediatric Trauma Score

	Points		
Component	+2	+1	–1
Size	>20 kg	10–20 kg	<10 kg
Airway	Normal	Maintainable	Unmaintainable
Systolic blood pressure	>90 mm Hg	50–90 mm Hg	<50 mm Hg
Central nervous system	Awake	Obtunded/loss of consciousness	Coma/decerebrate
Open wound	None	Minor	Major/penetrating
Skeletal	None	Closed fracture	Open/multiple fracture

The AIS, ISS, and AP are indices of trauma mainly from mechanical energy. One interesting question is the feasibility and usefulness of scoring that would include heat, electrical or chemical injuries, and asphyxiations. Mortality from burns is an exponential function of the surface area burned and the age of the patient (Rutowski, et al., 1976). Comparison of the predictability of the Trauma Score or Pediatric Trauma Score, as currently used, and statistically adjusting the weights of components, in studies of mortality and disability from burns, electricity, poisonings, and asphyxiations would be useful research projects. Since survival from both mechanical and thermal energy insults to human tissue are exponential functions of the injury severity to areas of the organism, there may be common biological processes at work that could be identified and targeted in treatment.

IMPAIRMENT AND DISABILITY. The study of outcomes other than the probability of death correlated to injury severity scoring has been limited. Length of hospital stays and disability from motor vehicle injuries are substantially predicted by the Injury Severity Score (Bull, 1975, Schluter, et al., 2005), but other scoring systems might improve predictability. It has been noted, for example, that a lesion to the eye that would be minor in another body area can cause blindness (Jorgensen, 1981). Ocular trauma scores predictive of poor vision have been studied but the correlations are modest (Cohen, et al, 2022). Head and spinal cord injuries with low AIS scores can result in substantial impairment (Conboy, et al., 1986; MacKenzie, et al., 1986).

The severity and persistence of disabling impairments from injury have not been extensively investigated. The National Health Interview Survey periodically notes prevalence (the proportion of the population with a condition at a given point in time) of certain impairments -- vision, hearing, speech, absence, deformities of extremities, and paralysis -- and the percent that occurred in the year of the survey

(Collins, 1986). However, the severity and prognosis of these impairments would require more detailed data. See http://www.cdc.gov/nchs/fastats/injury.htm for current information on injuries from NCHS.

Special studies of certain types of long-term disability have indicated the substantial excess of particular circumstances for certain types of injury. For example, the Utah Health Department's surveillance of spinal cord injury found that, during 1989-1991, 65 percent of nonfatal spinal injuries to motor vehicle occupants occurred in vehicle rollovers (Thurman, et al., 1995), about twice what would be expected from the proportion of occupant deaths that occur in rollovers.

The proposed impairment and disability measurement in Table 4-3 is an attempt to develop scales analogous to the Abbreviated Injury Scale (States and Viano, 1990). The developers adopted a seven-point scale, like the AIS, even though they couldn't identify seven points on some dimensions. As was the case with the Trauma Score and the Abbreviated Injury Score, the categories were formed based on clinical experience, but must be studied in terms of reliability and validity, and revised accordingly before widespread use.

Table 4-3. Proposed Impairment and Disability Scales

Mobility/Dexterity Impairment

1. *Minor:* Detectable impairment of mobility or dexterity but with intact functional ability, e.g., minor limp due to knee with degenerative arthritis, mild tremor, limitation of motion in some but not all digits, thumb normal, detectable weakness in hands.
2. *Moderate:* Walking distance limited to less than 1/4 mile. Uses cane occasionally. Can use stairs; difficulty in balance. Hands weak or usefulness impaired by tremor or spasticity. Typing and driving difficult.
3. *Serious:* Cane, crutches, prosthesis, and/or walker are necessary for walking except in dwelling. Stairs are difficult; railing is essential. Motor deficit of hands or extremities. Cannot type or use hand tools. Unilateral hand amputee.
4. *Severe:* Wheelchair is used by choice, but patient can stand and walk with apparatus, i.e., crutches or walker. Severe motor weakness, incoordination, or spasticity; self-feeding slow or uncertain.
5. *Very Severe:* Wheelchair is required for ambulation although patient can stand and walk short distances with assistance. Virtually complete motor paralysis. Virtually no hand function. Bilateral hand amputee.
6. *TotallyImmobile and Dependent:* Requires hoist for transfer; cannot stand; requires aide for activities of daily living. Has no useful function in upper extremities.

Cognitive/Psychological Impairment

1. *Minor:*Mild inappropriate behavior; occasional errors in language and arithmetic.
2. *Moderate:*Noticeable memory loss; difficulties with simple arithmetic; difficulty in self-expression; infrequent disorientation and dizziness. Mild mental retardation.
3. *Serious:* Occasional disorientation, significant memory loss or language impairment, and occasional signs of psychosis. Moderate mental retardation.
4. *Severe:* No memory for recent events; disoriented, psychotic, requires sheltered home, and speech unintelligible. Severe mental retardation.
5. *VerySevere:* No memory, total loss of speech; psychotic; usually requires institutional care. Profound mental retardation.
6. *Coma:* Vegetative; no purposeful response to stimuli; brain dead.

Cosmetic/Disfigurement Impairment

1. *Minor:* Normally covered, amenable to cosmetic makeup. Readily covered orthosis.
2. *Moderate:* Can be covered by cosmetics and/or forces change in dress; may require orthesis but not prosthesis.
3. *Serious:* Prothesis or cover-up required.
4. *Severe:* Readily observable, not amenable to cosmetic, prosthetic, or clothing cover-up.

Sensory Impairment

	Vision	Hearing	Sensation	Taste and Smell
1. *Minor:* Minor loss but does not interfere with usual activities; correctable with readily available aids such as glasses, hearing aids.				
2. *Moderate:*	Correctable to 20/100 in best eye.	Hearing loss not fully correctable.	26–50% loss to special senses or limbs.	Complete loss of taste or smell.

Pain Impairment

1. *Minor:* Occasional pain; analgesics not required or used; no interference with sleep.
2. *Moderate:* Occasional pain; more frequent or occasional use of nonnarcotic analgesics.
3. *Serious:*Constant or occasional severe pain; nonnarcotic analgesics required for sleep, work. Narcotic analgesics occasionally required.
4. *Severe:* Constant or severe occasional pain requiring narcotics or invasive therapy. Sleep poor; unable to work. Recreation and socialization severely limited.
5. *VerySevere:* Constant or severe pain requiring narcotics or invasive therapy. Sleep poor; unable to work. No recreation or socialization.
6. *UniformlyCauses Total Impairment:* Constant and/or occasional pain uncontrolled except with large doses of narcotics that affect the central nervous system. Incomplete control with invasive therapy.

Sexual/Reproduction Impairment

1. *Minor:* Decreases frequency of intercourse because of occasional pain or decreased libido.
2. *Moderate:* Inability to have satisfactory erection; loss of libido. Pain with intercourse. Reduced fecundity.
3. *Serious:* Complete loss of capability for an erection; loss of libido. Pain precluding intercourse. Complete absence of fecundity.

Disability Scale

0. *NoDisability:* Self-support (full-time work and full recreational activity compatible with patient's age).
1. *Minor:* Self-support with reduced recreational activity.
2. *Moderate:* Self-support with no recreational activity.
3. *Serious:* Independent living (limited or no assistance with activities of daily living); may be capable of part-time work.
4. *Severe:* Living at home but with assistance of aide less than four hours per day and/or assistance with shopping, meal preparation, and medications.
5. *Very severe:*Full care at home with aid more than four hours per day or institutional care but with ability to perform some activities of daily living.
6. *Extreme:* Institutional care with external life support systems such as mechanical respiratory assistance or tube feeding.

Source: States and Viano (1990).

The scales identify numerous potential outcomes of injury that indicates the increased need for prevention. One problem evident in the proposed impairment and disability scales (Table 4-3) is the presence of the same or similar criteria in both scales. Notice that ability to perform tasks such as typing, hand tool use, and

work are included in the mobility/dexterity and pain impairment scales; and self-support, which may require these activities, is in the disability scale. Similarly, "usually requires institutional care" is in the cognitive/psychological impairment scale, and "institutional care" is included in the disability scale. Thus, the scales are not independently determined and will, by definition, be correlated. Also, the disability scale does not have exhaustive categories; in the "extreme" group, persons may be institutionalized that do not require life support systems or tube feeding.

These scales need revision before being studied empirically, as recognized by the proponents who suggested that they be examined by expert consensus panels (States and Viano, 1990). Field tests to assess potential problems and establish weights for the effects of impairment on disability are also recommended before use in a full-scale research project. One obviously shouldn't just add up scales that may not be additive in effect and double counting of particular elements should be eliminated.

Reliability (sometimes called precision) refers to the repeatability of a measurement. For example, do different people who interview the same patient or review the same medical record produce the same score? Validity (sometimes called accuracy) refers to whether the dimension that one is attempting to measure is being measured. The reliability of data is often easily assessed by comparing the independent recording of the data, but the determination of validity is much more difficult.

If a scale is to measure injury severity relevant to survival, and it is strongly predictive of survival, it satisfies a major criterion for validity. A major validity test of an impairment scale is the extent to which it predicts the degree and permanence of disability.

The Functional Capacity Index (FCI) is a somewhat simpler attempt to measure the limitations of normal function and has been subjected to field testing. Also designed to mirror the AIS, it has 3 to 7 levels of indication of the ability to perform 10 activities: eating, excreting, sex, ambulation, use of hands and arms, bending/lifting, seeing, hearing, talking, and thinking. To assess inter-rater reliability, weights were assigned by raters from convenience samples of experts and white and blue-collar workers. Although raters assigned similar weights within dimensions, clinical experts tended to underestimate the importance of various activities relative to the other raters. There was also a large variation in intra-rater reliability among some scales when the ratings were repeated after two weeks (MacKenzie, et al., 1996).

Studies of disability in activities of daily living among the elderly indicate a hierarchy of factors (Dunlop, et al., 1997). One type of scale worth investigating is a scale where a number indicates a cumulative effect (Guttman, 1946). For example, if the data so indicated, a 1 would indicate "cannot walk", a 2 would indicate "cannot walk" and "cannot transfer from chair to bed", etc.

The researcher should not adopt any injury or disability scoring system without careful consideration of what is being measured relative to the hypotheses and possible uses of the research (MacKenzie, 2001). The injury severity scales mainly indicate the probability of death and are not very useful as measures of the probability of impairments and disabilities among those who survive (MacKenzie, et al., 1996). Some disability measures may be distorted because they are related to eligibility for insurance or governmental benefits (Aarts and DeJong, 1992; Bloch, 1992).

The extent to which a particular limitation is disabling depends on an individual's desires for specific activities and the environment in which they are pursued. There are three stages before disability that offer the opportunity for prevention: 1. pathology (e.g., traumatic denervation of an arm), 2. impairment (e.g., atrophy of muscle), and 3. functional limitation (no pulling strength). The effect on the person's life depends on the extent that pulling strength is necessary for work, recreation, and other activities (Pope and Tarlov, 1991). Scales have also been developed for drug addiction severity (Cacciola, et al., 2011).

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