AIS UNIFICATION: THE CASE FOR A UNIFIED INJURY SYSTEM FOR GLOBAL USE

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ABSTRACT

The Abbreviated Injury Scale (AIS), developed by the Association for the Advancement of Automotive Medicine (AAAM) is the most widely used anatomic injury severity scale in the world. However, different user groups have modified the AIS system to fit their needs, and these modifications prevent ready comparison and trending of data collected in these systems in the US and throughout the world. The US currently has 5 AIS based severity systems (NASS-88, NASS-93, AIS-85, AIS-90, NTSB) and two AIS based impairment systems (IIS and FCI) in use, with additional revisions forthcoming. Other modified AIS systems are known to be in use in the U.K. and Japan. The data collected in these systems cannot be accurately combined or compared without re-coding or the use of complex "mapping" programs.

With the increasing use of severity mapping of statewide hospital discharge data (ICD-9-CM and soon ICD-10-CM) and linking of country wide mortality data (ICD-9 and ICD-10) for engineering use, the relationship of the AIS severity systems to ICD-9/10, ICD-9-CM, and the proposed ICD-10-CM becomes more important. The recent creation of the national FARS-MCOD database for fatal motor vehicle (MV) injuries, and the mapping of statewide CODES data to NASS format are indicators of future data directions.

This paper compares five severity systems and two impairment systems in terms of purpose, code structure and use and discusses the reasons for the user modifications to these systems. With global "harmonization" encouraging greater sharing of international data, the paper also presents the relationship of the AIS worldwide to the larger scope of worldwide mortality (ICD-9/10) and US reimbursement (ICD-9-CM/10-CM) classification systems.

To resolve compatibility issues resulting from multiple injury systems, the authors propose a "unified" system for global use, configured by inputs from major AIS "data owners", users and analysts. Six key attributes of the unified system are: (1) Backward compatibility with historical data through "maps" so no data is lost. (2) "Scalable" to allow a simple level of use for developing countries, a more complex level for crash research and a detailed level for clinical hospital use, all with data compatibility. (3) Satisfy the needs of the engineering community for injury location information and aspect, and also the clinical requirement for precise injury description. (4) Integrated interface for overall severity scores, such as MAIS, ISS and NISS*. (5) Coordination with other injury data systems such as the ICD-9/10 mortality systems and ICD-9/10-CM reimbursement systems.** (6) Establish a structured process to maintain and upgrade the system, on a data compatible basis for the 21st century.

The authors believe that a "unified" system is critical to the preservation of the AIS as a worldwide standard. Unified data can provide a pool of consistent international data to support a variety of important research, prevention and treatment efforts and is essential to satisfy the global needs of the medical and engineering communities.

OVERVIEW OF ANATOMIC INJURY SYSTEMS

In order to propose a unified system, it is first necessary to understand why the users of each system developed it in a unique way. Five broad types of systems important to clinicians, engineers, regulators and vehicle researchers are listed in Table 1, along with the names of the systems falling under each type. Unless a unified system meets the needs of all intended users, it will not stay unified for long. To accomplish this goal, an understanding of the different system uses is required. The following is an overview of the various types and characteristics of systems in use in the US.

Table 1.
Types of Injury Systems

1. Severity / Location - NASS-88, NASS-93, NTSB
2. Severity / Identification - AIS-85, AIS-90
3. Mortality - ICD-9, ICD-10
4. Reimbursement - ICD-9-CM, ICD-10-CM, OIICS
5. Impairment / Identification - IIS, FCI

*MAIS - Maximum AIS, ISS - Injury Severity Score, NISS - New Injury Severity Score

**ICD - International Classification of Diseases

Injury Severity/Location Systems

These systems have three basic goals: locate the injury on the body, assign a threat to life rank to the injury and identify the source of the injury, if possible. They are currently used for collecting injuries relating to MV transport and aviation crashes. Injury location systems are of primary use to vehicle designers, regulators, manufacturers and researchers. To analyze the safety of vehicles or design safety interventions, the location and severity of occupant injuries is necessary. With this information, injuries can be matched with the source in the vehicle that caused the injury, and counter-measures developed.

A six point scale, (Table 2) based on a revision of the AIS (with some modifications to be discussed later) is used to rank threat to life in all location systems known to the authors. However, the part of the code that locates the injury varies between systems. To insure no injury location information is lost, location systems permit the coding of the location of an injury, even if the exact injury and its severity is not known. This requires an additional ranking level not used in AIS, usually designated as level 7 (Table 2).

Location systems do not need to identify an injury in terms of organ or system to a **clinical treatment level of detail** for the system to be useful. Information of the type necessary to assess quality or cost of care is not needed. As a result, some of the systems (NASS-88 & NTSB) do not uniquely identify an injury, i.e. several clinically distinct injuries may share the same injury code. However, it is imperative that the organization of the classifications permit computer parsing of the injury by body area, system, organ, etc. Injury severity/location systems include NASS/CDS-88, NASS/CDS-93, NTSB and modifications of these systems in use outside the US.

Injury Severity/Identification Systems

These systems have two basic goals: identify the injury in sufficient detail for treatment review and assign a threat to life rank to the injury. Injury identifier systems are of primary use in clinical settings or by medical researchers. Data coded with these systems is used to assess injury trends, quality of care and outcome. Precise definitions of the injuries are required in order to assess the treatment provided and outcome obtained.* As a result of this requirement, injury codes are unique; no injuries share the same code. A six point AIS severity scale, (Table 2) is used to rank threat to life. Coding of unknown injuries is discouraged, although a "9" severity level is allowed in cases for injuries where the severity is unknown.

Location of injury is not a major requirement of the users of these systems. The location in many cases does not affect the care or outcome and therefore is extraneous information. For example, an identification system might precisely specify which arm bone is broken, (i.e. radius or ulna) but will not identify whether it is the left or right arm. Identification systems are used by hospitals and researchers for all type of injuries, regardless of cause, including MVCs, falls, GSWs, etc. Perhaps as a result, these systems are less oriented towards collection or analysis of the source of a vehicle occupant's injuries. Injury sources are not captured for each injury, and the system is not generally organized to permit analysis for sources based on the location of the injury on the body. Injury identifier/severity systems include AIS-85, AIS-90 and modifications of these systems in use outside the US.

Table 2.
AIS Injury Severity Levels (Threat to Life)

0 = not classified as an injury (NASS and NTSB)
1 = minor
2 = moderate
3 = serious
4 = severe
5 = critical
6 = maximum
7 = injury, severity unknown (NASS)
88 = injury, severity unknown (NTSB)
9 = injury, severity unknown (AIS)
unknown if injured (NASS)
99 = other, (NTSB)

Mortality Systems

Mortality systems are the oldest of the five types of systems, with origins dating back more than 200 years. A mortality system has a single goal: to classify all **causes** of deaths for storage and statistical analysis. To meet this objective, less injury detail is required than that recorded in severity, impairment or reimbursement systems. Additional information, which might be useful for care or treatment of injuries is not required. The source of each injury is not recorded and no severity information is recorded, perhaps since all individuals are deceased. Injuries of different severities in other systems, and injuries with different sources may be coded under the same code in a mortality system. The World Health Organization's (WHO) International Classification of Diseases, 9th revision (ICD-9), is an international standard currently used to report US

*Injury identifier codes "Pre-dots" began with AIS-85. AIS-80 and earlier AIS revisions did not include injury codes, only severity digits, but were used for outcome analysis.

mortality data.* Injuries are not defined as "**causes**" of death according to ICD-9 and ICD-10. Injuries are "nature of injury" (N-codes) and are only recorded when associated with a specific cause. As a result, two types of codes are recorded for an injury in the ICD-9 mortality system: a single code for cause of the injury (i.e. motor vehicle crash) and from one to twenty nature of the injury codes (i.e. crushed skull, broken ribs, etc.).

Reimbursement Systems

A reimbursement system has a single purpose: to classify and store conditions and procedures so that charges can be assigned and utilization reviewed. Injuries are a subset of all possible conditions including diseases, poisoning, burns, related complications and procedures. One major reimbursement system in the US is the ICD-9-CM (clinical modification).**

The ICD-9-CM is an expanded and altered version of WHO's ICD-9 mortality system. The "CM" includes more detail, organized in a different way, in order to capture the information required for billing and utilization. In spite of its name, the ICD-9-CM is **not** an international standard and is not under the exclusive control of the WHO. The similar names but different purposes and details of the ICD-9 and ICD-9-CM can cause confusion. ICD-9-CM coding is required by the US government for reimbursement for Medicare or Medicaid and is also required by states with rate setting systems. Many states make publicly available statewide hospital discharge data in ICD-9-CM format, and similar census data is available for the national Medicare database. Diagnoses and procedures coded in ICD-9-CM determine the DRG (Diagnostic Related Group) that specifies the reimbursement level used by U.S. Public Health Service and the Health Care Finance Administration.

No severity, impairment or source of injury information is part of the ICD-9-CM nature of injury code. The code cannot be "parsed" to give the location of the injury. Only the most significant injuries (from a reimbursement standpoint) are generally recorded by coders, and the coding may be affected by reimbursement considerations. As with mortality systems, injuries with different severities in other systems and injuries with different sources may be coded together under the same reimbursement code.

Another classification system is the Occupational Illness and Injury Classification System or OIICS, administered nationally by the Bureau of Labor Statistics. The creators of this system considering using the ICD-9-CM system for their data, but found it too complex. The OIICS system is designed to capture data on occupational injury or illness. The system includes codes for the nature of injury or illness, part of body affected, source of the injury, manner of event or exposure causing the injury and the secondary contributing injury source. No severity or impairment information is included in the code.

Impairment/Identification Systems

An injury with low severity (threat to life) does not necessarily have low impairment, either as measured by a quantitative scale or by public perception. Bilateral eye injuries causing permanent blindness may have a severity of AIS-1 or 2 (minor or moderate) in terms of threat to life, but have a large effect on lifestyle and long term impairment. Impairment is the complement to severity, and while this is a developing area, the use of impairment systems will undoubtably grow.

The Injury Impairment Scale (IIS) and Functional Capacity Index (FCI) are two different impairment systems, both based on the AIS-90 identification/severity system. They are designed to use the same injury code structure as the AIS-90, but instead of severity assign an extension to the code that corresponds to the loss of function resulting from that injury after healing has occurred. The IIS and FCI each map into their own subset of all the AIS-90 codes.

INJURY SYSTEM DETAILS

Each system contains a dictionary of injury descriptions, at least one code to represent each injury, and other attributes of the injury, which may include severity, impairment or location data. These characteristics are described for each of the main systems.

AIS-85

The AIS-85 was the first AAAM system to combine the six point severity scale with numeric codes to designate specific injuries. AIS-85 uniquely identifies 1224 injuries with a 5 digit numeric "pre-dot". Injury aspect information (left, right, central, bilateral) is only included for a few bilateral codes. There are eight body chapters that could be used for injury location, except that all skin injuries are grouped in a ninth chapter, essentially preventing easy computerized location analysis. In contrast to ICD-9-CM, AIS requires the coding of **all** injuries for an individual, not just the most severe or costly. A sample code appears in Table 3.

*The US has announced the intention to shift to the ICD-10 revision in 1999.

**A preliminary version of the ICD-10-CM was released for review in late 1997.

Major Uses of AIS-85 - Some hospitals have not converted to AIS-90 and continue to compile hand coded trauma registry data in AIS-85. However, the widest use of AIS-85 is output from the automated "mapping" program used to compute severity from ICD-9-CM hospital discharge data. Other uses include numerous studies in the literature, NHTSA Study Center crash cases and MVC data bases in parts of the UK and Australia.

Table 3.
AIS-85 Code Dissection

Code Number = 32305.4
Description = Le Fort III maxilla fracture
3 = AIS-85 body chapter (total of 9) - Face
23 = organ or specific area - maxilla
05 = injury succession number (5th listed)
4 = AIS-85 Severity, 1 to 6, or 9 (injury of unknown severity), 4 specifies a severe injury

Note: The Body chapter digit is partly amenable to computerized parsing for location analysis, but this analysis is confounded by the collection of all skin injuries in a separate body chapter. Organ & injury succession numbers are not configured for parsing.

AIS-90

The AIS-90 is a revision of the AIS-85. Extensive changes were made to the injuries included, particularly in the head chapter. There are 1315 injuries uniquely identified. The injury description code was expanded from 5 to 6 digits, and was therefore changed for all injuries. Injury aspect information is included only for a few bilateral codes. Injury location is limited to eight body chapters, with an additional chapter for "other". Skin injuries, with the exception of burns and some other injuries, were put into the body chapter in which they occurred. This allowed computerized injury analysis by body chapter location for most injuries. Organization by type of anatomic structure was introduced so that computer analysis could be carried out below the body chapter level. As with AIS-85, AIS-90 coding rules require the coding of **all** injuries.

Table 4 displays the same injury shown for AIS-85 in Table 3. Note that all parts of the code are different from AIS-85, including severity. However the severity of the injury could be the same if a >20% blood loss occurred. However, blood loss information was not collected in AIS-85, so a direct comparison between the codes is not possible.

AIS-90 Use - Hand coded AIS-90 data exists in a few state-wide trauma systems for about 18,000 individuals per year. The AIS-90 data is sometimes mixed with AIS-85 data because coders may not record, or users may delete the injury identification code "pre-dots". AIS-90 is also used in individual hospitals' trauma registries which typically contain less than 2,000 cases per year, NHTSA Study Center crash cases and numerous studies in the literature. Modified versions of the AIS-90 are used in MVC databases in parts of the UK and Japan. Unlike AIS-85, relatively less "mapped" data exists for AIS-90, since the mapping computer program was just released in late 1997.

Table 4.
AIS-90 Code Dissection

Code Number = 250808.3
Description = Le Fort III maxilla fracture
2 = AIS-90 body chapter (total of 9) - Face
5 = type of anatomic structure (6 types) - skeletal
08 = specific anatomic structure (19 types)
08 = level (consecutive number, 00 or 99)
3 = AIS-90 severity, 1 to 6, or 9 (injury of unknown severity), 3 specifies a serious injury

Notes: Body chapter parsing analysis confounded for burns and degloving injuries, since these injuries are not coded in the body chapter where they occur. Anatomic structure parsing analysis confounded for burns.

The code 250810.4 is used (+1 to severity) rather than 250808.3 if blood loss >20%.

NASS-88

In the middle 1980's NHTSA required an injury location and severity system to correlate occupant injuries and severities with injury sources for its Crashworthiness Data System (CDS) database. At the time, the AAAM system, AIS-80, did not record any injury information beyond the severity digit. Therefore, to provide injury location information, NHTSA adopted another system, known as the Occupant Injury Classification, or OIC. This permitted the analysis of the location of skin contacts and other injuries relative to the sources of the injuries, a vital part of MVC injury prevention. The authors refer to this system as NASS/CDS-88 or NASS-88 and it was used for data collected by NHTSA between 1988 and 1992.

As a location system, NASS-88 focuses on location information, not treatment detail. The injury code consists of four alphabetic characters and one severity digit. There are 20 body chapters, versus 9 in the AIS-85 system, to permit finer resolution in the location of injuries. Unlike AIS-85 and AIS-90, skin injuries are always coded in the body chapter and with the detailed aspect in which they occur. Injury codes are not unique and may be used to specify different injuries at the same location with different severities. As a result, there are 5,698 injury descriptions, but only 3,192 unique injury codes. NASS coding rules require the coding of all injuries, even when severity is not known. This is done to retain body contact point information. To accomplish this, NASS created a new severity level of 7 for these injuries. The recording of injuries of unknown severity makes the calculation of ISS different for NASS and AIS cases. AIS prohibits the calculation of ISS for patients with unknown severity, NASS allows it.

Table 5.
NASS-88 Code Dissection

Code Number = FCFS-4
Description = Le Fort III maxilla fracture
F = NASS-88 body chapter, Face (total of 20)
C = aspect/location (max of 10 aspect codes) - central
F = lesion (19 types) - fracture
S = system/organ (22 types) - skeletal
4 = Severity, 1 to 6, or 7 (injury of unknown severity), 4 specifies a severe injury

Note: All parts of the code (body chapter, aspect, lesion, organ, severity) are amenable to computerized location analysis.

The NASS-88 system was designed to be easy to code and analyze, and all parts of the injury code are designed to parse for computer analysis. The coding manual relies on the use of "wildcards" to specify the code structures, with the permissible values for the wildcards varying by body chapter. This approach makes it necessary to first "expand" the manual in order to determine all of the defined injuries. It also makes it difficult to identify errors in coding, as a listing of all the defined codes after expansion is not included. In contrast, neither AIS-85 or AIS-90 use wildcards.

NASS-88 Use - NHTSA's NASS/CDS crash database contains 50,000 individuals and 158,000 injuries, collected by NHTSA's investigators over the period 1988-1992. **This is likely the largest uniform hand coded severity database in the world.** Using the mapping programs developed by two of the authors it is possible to combine the NASS-93 and NASS-88 databases to produce a unified database with 80,000 individuals and 250,000+ injuries. NASS-88 is also used in numerous U.S. MVC studies in the literature.

NASS-93

Starting with the 1993 CDS data year, NHTSA ceased using the NASS-88 injury system and changed to a system the authors call NASS/CDS-93, or NASS-93. This system is based on the AIS-90. Since the AIS-90 is an injury description system, NHTSA modified the system to collect location information. The modifications included changing injury codes for skin injuries by placing burns and other injuries in the body region in which they occur, and adding an aspect digit (up to ten aspects) to every code to specify injury location.

Table 6.
NASS-93 Code Dissection

Code Number = 250808.3,4
Description = Le Fort III maxilla fracture
2 = NASS-93 body chapter (total of 9) - Face
5 = type of anatomic structure (7 types) - skeletal
08 = specific type of anatomic structure (19 types)
08 = level (consecutive numbers, 00 to 99)
3 = AIS-90 severity, 1 to 6, or 7 (injury of unknown severity), 3 specifies a serious injury
4 = aspect (10 types), central

Notes: Modifications made to original AIS-90 codes allows parsing for body chapter, anatomic structure, type of structure and severity.

The addition of aspect resulted in some conflict with original AIS-90 codes. These have largely been eliminated by successive modifications to NASS-93.

The code 250810.4,4 is used (+1 to severity) rather than 250808.3,4 if blood loss >20%.

These modifications nearly tripled the number of AIS-90 codes, from 1315 to 3176. However, unlike NASS-88, the codes are unique. The injury manual added "wildcard" codes (like NASS-88) to the original AIS-90 structure to designate which aspects are applicable to each code, and which body chapters apply to burn codes. This requires the manual to be "expanded" to locate undefined injuries. Even with the NHTSA modifications to enhance location, the drop in the number of body regions (to nine) makes the system less sensitive for computer analysis of injury location than the 20 chapters in NASS-88. For example, it is not possible to identify skin injuries to the "lower leg" - all leg injuries are now in "lower extremities" and could be located in the upper or lower leg, knee, ankle or foot. NASS-93 coding rules require that all injuries be coded, and like NASS-88, there are special injury codes of severity 7 for injuries of unknown severity. As with NASS-88, this results in different calculations for ISS than in the AIS system.

NASS-93 Use - NHTSA's NASS/CDS crash database expands by about 10,000 individuals and 30,000 injuries each year. The total for 1993 to 1996 is more than 100,000 injuries. Within two years, the NASS-93/CDS database will replace the NASS-88/CDS database as the largest uniform hand coded injury database in the world.

Using the authors' "Crashmap" program, NASS-93 injury codes and severity levels can be produced from statewide hospital discharge linked Crash Outcome Data Evaluation Study (CODES) data. This process can assign NASS codes and severity levels for tens of thousands of injuries for the thousands of individuals hospitalized from MVCs in the CODES states each year.

Other uses include 100-200 cases per year from NHTSA's Special Crash Investigation (SCI) group, 500 - 1000 cases a year from NHTSA CIREN study cases and numerous studies in the literature. The Transport Canada national MVC data base is also reported to use NASS-93.

NTSB

The National Transportation Safety Board (NTSB) has the charter of oversight of aviation, pipeline, marine and interstate truck crashes. The NTSB maintains a database of all commercial and general aviation crashes exceeding an injury and damage threshold. In the 1980's the NTSB began to use an AIS based system to record injuries for some of these crashes. The system is an injury location system using an 8 digit numeric injury location with a two digit AIS severity. The source of the injury is also recorded and attached as an extension to the code.

Table 7.
NTSB Code Dissection

Code Number = 0299040103
Description = Le Fort III maxilla fracture
02 = Body chapter (total of 24) - Face
99 = Aspect (total of 4) - Other
04 = Lesion(19 types) - Fracture
01 = System Organ (24 types) - Skeletal
03 = AIS severity, 00 to 06, 88 (injury of unknown severity), 99 Other, 03 specifies a serious injury

Note: All parts of the code are amenable to computerized parsing for location analysis

The NTSB system is similar in concept to NASS-88, but uses numeric rather than alphabetic identifiers. It does not uniquely identify codes. The definitions of body chapter, aspect, lesion and system/organ are different than the NASS or AIS systems. The sample case in Table 7 shows the same injury used previously.

NTSB Use - The system is designed for use in the national database of all aircraft crashes with significant damage or injury. This includes 37,000 crashes for the period 1983-96. Injuries and seating information for crash occupants are compiled in supplements K & L, but not for every crash.

ICD-9

ICD-9 is an outgrowth of what was originally a mortality only system. It includes morbidity, but in the US the largest use is to present national mortality data. In this classification system, injuries are assigned numbers, basically in sequence. The code numbers are not organized to allow parsing for body region as in the NASS or NTSB systems. The ICD-9 system is often confused with ICD-9-CM, which is a US system used for reimbursement. The two systems are not identical.

Table 8.
ICD-9 Code Dissection

"N" or Nature of Injury Code Number = 874.9
Description = Open wound of neck, other and unspecified parts, complicated
874 = Three digit numeric disease/injury identifier
9 = One digit detail qualifier after decimal
No aspect, severity or impairment information

In the context of ICD-9 mortality data, this code is used for **decapitation.** In unlinked FARS, this injury would be represented only by "K" for killed.

Note: ICD-9 codes cannot be parsed for computerized location analysis.

In 1998, the ICD-9 began a new and prominent role in crash research with the linkage of nationwide Fatal Crash Reporting System (FARS) and Multiple Cause of Death (MCOD) mortality data. FARS-MCOD provides more detailed causes of death (in ICD-9 format) for MVCs. **FARS-MCOD is the first US database with injuries coded in an international standard, and will likely replace unlinked FARS because of the increased injury information the ICD-9 codes provide.** When linkage of all FARS years is complete, FARS-MCOD will contain ICD-9 injury codes for more than a million persons.

ICD-10

The ICD-10 is a major revision of the ICD international standard. Such revisions occur every 10 or 20 years. The US is scheduled to adopt this system for reporting of mortality data in 1999. The code structure, injury organization and coding rules are changed from ICD-9.

Table 9.
ICD-10 Code Dissection

Injury Code Number = S18
Description = Traumatic Amputation at Neck Level
S18 = 3 digit alphanumeric disease/injury identifier
May have one digit detailed qualifier after decimal, but none in this case
No aspect, severity or impairment information

Note: ICD-10 codes cannot be parsed for computerized location analysis.

ICD-9-CM

The "CM" or clinical modification of the ICD-9 was developed in the US to expand the morbidity part of the ICD-9 to capture information important for the US national reimbursement systems. It is not an international standard, but is used by virtually every US hospital. It is a classification system where injuries are assigned numbers, basically in sequence. The code numbers are not organized to allow parsing for body region as in the NASS or NTSB systems. However, codes for skin injuries contain more location information (although not Aspect) than the 9 body chapters in NASS-93 can record.

Table 10.
ICD-9-CM Code Dissection

Diagnosis Injury Code Number = 874.9
Description = Open wound of neck, other and unspecified parts, complicated
Code looks like ICD-9
874 = Three digit numeric disease/injury identifier
90 = One or two digit detail qualifier after decimal
No aspect, severity or impairment information

Table 8 and 10 show the same code. **In ICD-9-CM this is a "bucket" code** and may contain unspecified open wounds to the neck, as opposed to decapitation in ICD-9 mortality data.

Note: ICD-9-CM codes cannot be parsed for computerized location analysis.

The ICD-9-CM is becoming increasingly important to crash researchers as conversion programs, such as "Crashmap", are used to convert CODES statewide ICD-9-CM discharge and ED data to the NASS-93 injury code format familiar to crash engineers.

ICD-10-CM

The ICD-10-CM is a major revision of the ICD-9-CM US reimbursement system. This revision is currently under review, and may be introduced in 2001 or 2002. The code structure, injury organization and coding rules have all changed from ICD-9-CM, and while it is based on the ICD-10 there are many differences, including codes that are not used and the inclusion of limited Aspect information for laterality (left, right). The code numbers are more organized than ICD-9-CM, but still do not allow parsing for body region as in the NASS or NTSB systems. Codes for skin injuries contain more location information than the 9 body chapters of NASS-93, and include aspect. CODES ICD-10-CM data may in the future supply more skin contact location information for MV researchers and engineers than NASS-93.

Table 11.
ICD-10-CM Code Dissection

Injury Code Number = S11.80
Description = Unspec. open wound of other parts of neck
S11 = Three digit alphanumeric disease/injury identifier (open wound of neck)
.80 = One or two digit detail qualifier after decimal - in this case unspecified wound to neck
Aspect is third digit to right of decimal (not this code)
No severity or impairment information

There is no code in ICD-10-CM equivalent to the S18 decapitation code in ICD-10 shown in Table 9, as this is not currently a treatable condition.

Note: ICD-10-CM codes cannot be parsed for computerized location analysis.

FCI

Impairment scales attempt to assess the long term effects of injuries after healing has occurred. The Functional Capacity Index (FCI) is an impairment scale based on the AIS-90 system, jointly proposed by NHTSA and The Johns Hopkins University. The FCI uses a subset of the 1315 AIS-90 codes, and assigns a non-zero impairment to 324 of those codes. Impairment is measured by function in 10 dimensions: eating, excretory, sex, ambulation, hand/arm, bending, vision, hearing, speech and cognitive. Each dimension has its own set of limitation levels (a-f). A continuous rating of whole body impairment is computed from the dimensions (WBFCI) and assigned a value between 0.00 and 100.00. The FCI is currently under review.

Table 12.
FCI Code Dissection

Injury Code Number = 250808.3aaaaaaaaaa00.00
Description = Le Fort III maxilla fracture
"Predot" and Severity = 250808.3 same as AIS-90
2 = AIS-90 body chapter (total of 9) - Face
5 = type of anatomic structure (6 types) - skeletal
08 = specific anatomic structure (19 types)
08 = level (consecutive number, 00 or 99)
Ten Dimension Limits aaaaaaaaaa = no impairment in eating, excretory, sex, ambulation, hand/arm, bending, vision, hearing, speech, cognitive areas
WBFCI = 0 on continuous scale of 0 to 100.00, no whole body impairment
No Aspect

IIS

The Injury Impairment Scale (IIS) is an impairment scale developed by the AAAM based on the AIS-90 system. It uses an ordinal 0-6 scale to indicate impairment. Of the 1315 AIS-90 codes defined, the IIS assigns impairment codes to 508. It is also currently under review.

Table 13.
IIS Code Dissection

Injury Code Number = 250808 2
Description = Le Fort III maxilla fracture
"Predot" = 250808 same as AIS-90
2 = AIS-90 body chapter (total of 9) - Face
5 = type of anatomic structure (6 types) - skeletal
08 = specific anatomic structure (19 types)
08 = level (consecutive number, 00 or 99)
Impairment = 2, compatible with most but not all normal function
No Aspect

SYSTEM DIFFERENCES

Code and System Structure

The authors, Bradford et al and the IIHS have presented papers on the differences and incompatibility of the AIS, NASS, ICD-9 and ICD-9-CM systems. Tables 3 through 13 have shown some of the differences in the code structures for the AIS, NASS, ICD, FCI, IIS and NTSB systems.

Table 14 illustrates the differences between the NASS and AIS systems in terms of the number of codes and the distribution of the codes by severity. The total number of injury descriptions varies from 1224 in AIS-85 to 5,698 in NASS-88. The percentage and number of codes at any severity level are also different between the systems. Examination at a finer level will uncover many other differences, including injuries which are not included in all systems, different body chapters for the same injury, and major variations in the way skin injuries are recorded. Of particular interest are the many changes in the head body chapter injuries between AIS-85 and AIS-90. Also, identical injury descriptions including "one bilateral" versus "two left/right" aspects in different revisions or systems can cause double counts. These details are covered in the authors' other papers.

Table 14.
System Severity Level Distributions and Total Injury Code Counts

Severity	AIS85 No Aspects		AIS90 No Aspects		NASS88 Aspects Expanded		NASS93 Aspects Expanded	
0	0	0.0%	0	0.0%	1	0.0%	1	0.0%
1	166	13.6%	246	18.7%	1538	27.0%	955	30.1%
2	289	23.6%	399	30.3%	2139	37.5%	971	30.6%
3	374	30.6%	343	26.1%	1213	21.3%	771	24.3%
4	217	17.7%	156	11.9%	415	7.3%	248	7.8%
5	151	12.3%	144	11.0%	200	3.5%	193	6.1%
6	27	2.2%	22	1.7%	38	0.7%	22	0.7%
7	0	0.0%	0	0.0%	154	2.7%	15	0.5%
*9	0	0.0%	5	0.4%	0	0.0%	0	0.0%
Totals	**1224**	**100.0%**	**1315**	**100.0%**	**5698**	**100.0%**	**3176**	**100.0%**

Notes: Total for unique codes in NASS-88 is 319[illegible]
AIS-90 and AIS-85 use 9 for "Injury, Unknown Severity"
NASS-88 and NASS-93 use 7 for "Injury, Unknown Severity

Table 15 summarizes other characteristics of the systems. Differences include a wide range in the number of body chapters for location of injuries, (none to 24) the

Table 15.
Table of System Characteristics

	AIS85	AIS90	NASS88	NASS93	NTSB	ICD-9	ICD-10	ICD-9-CM	ICD-10-CM
Body Chapters	9	9	20	9	24	No	No	No	No
Aspect	No	No	Yes	Yes	Yes	No	No	No	Proposed
Injury Code	5 numeric	6 numeric	4 alpha	6 numeric	8 numeric	4 numeric	4 alphanum	5 numeric	6 alphanum
Severity	1 digit	1 digit	1 digit	1 digit	2 digits	No	No	No	No
# Injury Desc.	1224	1315	5698	3176	unknown	>800*	963*	2030*	>2030*
Unique Injuries	Yes	Yes	3192	Yes	No	Yes	Yes	Yes	Yes

*Note: Includes codes in injury section only ICD-9/9-CM 800-959, ICD-10/10-CM S00 to T69

number of characters in the injury code (four to eight) and whether they are numeric, alpha-numeric or alphabetic, and whether the system includes aspect information (left, right, central, etc). The NASS-88 and NTSB location systems assign the same injury code to several injury descriptions at the same location, and hence have more injury descriptions than unique injury codes.

Threat to Life Baseline

Another important issue is the compatibility of the severity scale between these systems. The AIS severity scale is not "static". As medical technology advances, the threat to life of a given injury can diminish. An injury that 10 years ago in NASS-88 was a "3" level (serious), and under AIS-85 was a "2" level (moderate), may under the revised AIS-90 be a "1" level (minor). This type of change is illustrated in Tables 16 and 17. Although these adjustments in threat to life are appropriate for clinical use, they confound analysis of injury severity over time.

The time frame in which injury severities were assigned establishes the baseline of medical technology used. The authors call this factor the TLB or Threat to Life Baseline.

For severity system data users who wish to compare or trend data collected from different revisions of AIS systems, differences in the TLB make analysis complex. For example, it may not be possible to determine whether reductions in injury severity of MVC occupants over time is caused by vehicle safety interventions or the change in severity of injuries due to a TLB revision. Table 16 illustrates this point for a MVC occupant with the same injuries measured in AIS-85, AIS-90, NASS-88 and NASS-93. **The result is that the Maximum AIS by ISS Body Region, overall MAIS and the ISS for the individual varies with the recording system used.** The individual shown might rank as "major trauma" (e.g. ISS>15) in one system and not in another.

Table 16.
Comparisons of Severity Levels

An 11 year old child sustains a fractured femur, a dislocated knee and a LeFort III fracture of the maxilla (with ≤ 20% blood loss), and an eyelid laceration in a motor vehicle crash in a snow storm.

Injury Description	AIS-85	AIS-90	NASS-88	NASS-93
ISS Body Region - Extremities or Pelvic Girdle:				
Right femur fracture, NFS, (age <12)	92601.3	851802.2	TRFS-3	851802.2,1
Right knee dislocation, NFS	91805.3	850806.2	KRDJ-3	850806.2,1
Mais for Body Region:	3	2	3	2
ISS Body Region - Face:				
LeFort III fx of maxilla (with blood loss ≤ 20% by volume), aspect is central	32305.4	250808.3	FCFS-4	250808.3,4
Left eyelid laceration	10301.1	210600.1	FLLO-1	297602.1,2
Mais for Body Region:	4	3	4	3
ISS Body Region - External:				
Hypothermia, 33-32 C	(no code)	919604.2	(no code)	(no code)
MAIS for Body Region	N/A	2	N/A	N/A
MAIS Overall	**4**	**3**	**4**	**3**
ISS	**$3^2+4^2=25$**	**$2^2+3^2+2^2=17$**	**$3^2+4^2=25$**	**$2^2+3^2=13$**

Table 17.
Example of Variation in Threat to Life Baseline

Injury Description	Injury Codes			
	NASS-88	NASS-93	AIS-85	AIS-90
Heart laceration, NFS	CCLH.5	441008.3,4	51703.5	441008.3
Left elbow dislocation	ELDJ.2	750630.1,2	81504.2	750630.1
(two codes in NASS-88)	ELDJ.3			

Injury Description	Injury Severity			
	NASS-88	NASS-93	AIS-85	AIS-90
Heart laceration, NFS	5	3	5	3
Left elbow dislocation	2 or 3	1	2	1

Simply because severity data is ranked using a code with a 6 point AIS scale attached does not make it automatically comparable. The threat to life baseline must also be the same between the systems. **This point is not well known or understood.** If the TLB is not the same, then a "map" is required to adjust the severity of each injury code before comparisons between systems can be made. Examples such as shown in Table 16 illustrate the importance of having a way of normalizing the TLB between systems before comparing or trending severities or overall body scores, such as MAIS, ISS or NISS.

Table 17 illustrates how variations in the Threat to Life Baseline can cause differences in severity of one and two points across the AIS and NASS systems. Since ISS uses the square of the severity level, it amplifies these differences. For example a two point change from a 3 to a 5 changes the ISS by 16 points (3 x 3 =9 vs 5 x 5 =25). The heart laceration code shown in Table 17 illustrates the importance of this issue. This code, with a two point severity change, comprises **20%** of all the AIS-5 level injuries in NHTSA's NASS-88 database.

Table 17 also demonstrates the related issues of code counts and "numerical consistency". For example, to answer the question, how many elbow dislocations were in the NASS/CDS data base between 1988 and 1996, Table 17 shows it is necessary to count two "pre-dot" codes in NASS-88 for the data from 1988-1992 and one pre-dot code in NASS-93 for the data from 1993-1996. Further, the appropriate aspect codes must also be accounted for, in this case: left, right and unknown. The AIS based systems lack rules for diagnosis or code counting, so each case must be considered individually.

Before answering the question, "Did new driver side arm rests introduced in 1994+ model years reduce the number of left elbow dislocations of AIS-3 compared to prior years?", it is important to recognize that the NASS coding system eliminated all AIS-3 elbow dislocation codes when it was revised in 1993. Therefore, there would be zero AIS-3 elbow dislocations in 1993+ data to compare to prior years.

The only current method to systematically address the above issues is the use of a NASS-93 to NASS-88 conversion map, which identifies the relationships between the old and new codes and severity levels so that proper data queries and analyses can be conducted.

SYSTEM CONVERSION BY MAP

One way of dealing with the incompatibility issues presented in this paper is to keep data from each system and revision separate and re-code any data necessary for trended analysis. This is an expensive and time intensive approach. Another approach is to develop computerized conversion "maps" that convert between the injury descriptions in the systems. The authors have created or worked on many of

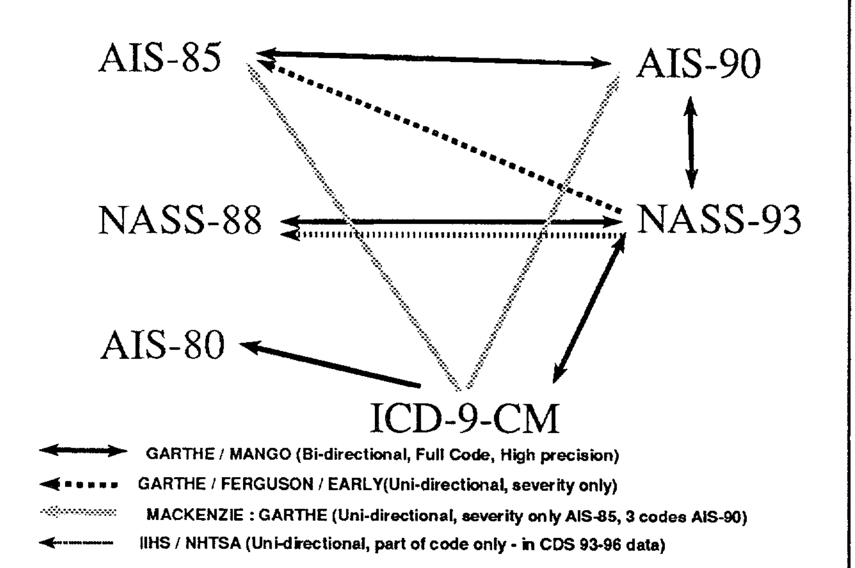

Figure 1. AIS-NASS-ICD Conversions

the maps currently in use, which are illustrated in Figure 1.

Maps can help to resolve issues caused by code, severity and injury count differences. However, as the number of revisions of each system grows the number of required conversions grows geometrically. If each of the AIS, NASS, ICD and ICD-CM systems shown in Figure 1 are revised, then the total number of maps required to convert between all systems grows to 36. With revisions forthcoming for ICD-10, ICD-10-CM and AIS, this possibility looms in the near future. Constructing the conversions becomes an untenable task; an effort larger than revising the base system. Even if the additional conversions were constructed, it is doubtful that most users would be able to keep on hand and apply all the maps that might be necessary to adjust their data.

A further complication is that maps perform more precisely going from the system with the most detail (typically the latest revision) back to the system with less detail (the earlier revision). Therefore, to obtain the highest precision, combined data must be converted to the "old" format, partially defeating the purpose of revising the systems in the first place.

The difficulties with the expanding number of conversions, and the confusion experienced by users of data collected in different systems is one of the primary reasons the authors propose the creation of a unified injury system.

HAND CODED VERSUS MAPPED DATA

Another major factor in considering a unified system is the evolution in the type and use of injury data. Hand coded data is most familiar to clinicians. To produce the data, coders assign a set of severity codes from a severity dictionary to a case after reviewing information from medical records and other primary sources. An experienced, trained coder can code 3-4 cases per hour. The detail and accuracy produced is high, but the process is relatively expensive. The expense limits the amount of data that is coded this way to thousands of cases.

At one time, the pure AIS system was used to collect the largest databases, which generally belonged to regional, or sometimes statewide trauma systems. However, Figure 2 shows that this is no longer the case. While individual hospitals may have thousands of hand coded AIS cases in their trauma registries, this data is rarely combined with other hospital's data and made available for public analysis. Meanwhile, the requirements of vehicle engineers and policy makers has resulted in massive hand coded national databases for MV crashes. NHTSA's NASS-88 & NASS-93 CDS databases contain over 80,000 persons with 250,000 injuries for the period 1988-96, and are growing at the rate of 30,000 injuries per year.

Mapped data is becoming more popular, especially for the engineering community. Hospital inpatient, observation stay and ED data, collected in reimbursement formats are available statewide and in some cases nationally for millions of individuals. By converting the data from these formats to a severity format using a computerized "map" or conversion, information on large numbers of cases can be obtained at a low cost compared to hand coding.

In most cases, the precision of the maps is not at present equal to re-coding the cases by hand; however, the database sizes are so large that the data remains useful even with the lower level of precision. Of particular importance in this area are the conversions to severity data from the ICD-9/10 mortality and ICD-9/10-CM reimbursement systems. One area that maps now may be superior to hand coded NASS/AIS data is in the analysis of skin contact injuries. NASS-93 and AIS-90, with only 9 body chapters are limited in the ability to precisely locate extremity injuries, as mentioned earlier. ICD-9-CM and to a greater extent, ICD-10-CM (with aspect) contain more information on the location of skin injuries than NASS-93 and AIS-90, and nearly as much as the 20 body chapter NASS-88. As a result, data mapped from ICD-9-CM/10-CM systems (such as CODES data) can produce data with better location resolution than the NASS-93 system. This is another factor which may contribute to the expanded use of mapped data.

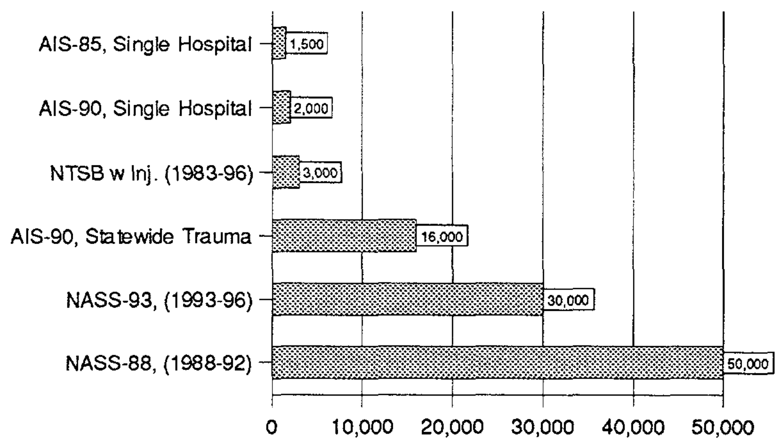

Figure 2. Hand Coded Database Sizes, (cases).

The driving force behind the refinement of the mapping approach is the magnitude of the data that can be converted with it. Figure 3 illustrates how the mapped dataset sizes dwarf even the massive NASS/CDS database, with 380,000 individuals in MV crashes and tens of thousands of injuries available from one CODES state for one year. If the precision of the maps can be improved enough, the sample sizes offer whole new areas for researchers, regulators and engineers to study.

SUMMARY OF CURRENT SITUATION

There are at least five variations of the AIS severity system in use, none of which collect data that is directly compatible with the others. Further, computed scores, such as ISS, cost (HARM) or impairment weights cannot be applied between the systems without adjustment.

Engineering users require injury location type systems, while clinical users require injury description systems. Currently, no single system combines enough information for both groups. Hospital users tend to use their data within their hospital or center, while engineering users want to combine and analyze data on a national basis. The need for data has resulted in the development of engineering based databases (NASS-88, NASS-93), which are much larger and more accessible than the hospital (AIS-85, AIS-90) injury description type databases. The multitude of severity systems in use makes the comparison or trending of data difficult, and can lead to mistakes in analysis when data is combined without corrections.

With the increasing use of severity mapping of statewide CODES hospital discharge data (ICD-9-CM and soon ICD-10-CM) and linking of country wide mortality data (ICD-9 and ICD-10) for engineering use, the relationship of the AIS severity systems to ICD-9/10, ICD-9-CM, and the proposed ICD-10-CM becomes more important. The recent creation of the national FARS-MCOD database for fatal MV injuries, and the mapping of statewide CODES data to NASS format are indicators of future data directions.

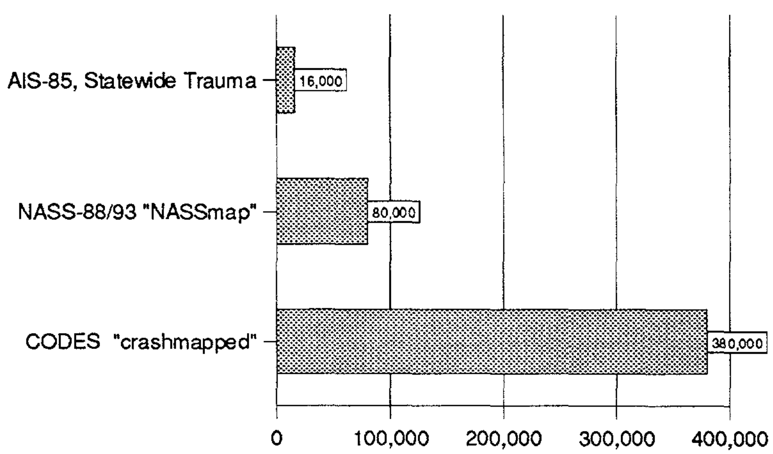

Figure 3. Mapped Database Sizes (cases).

The proposed adoption of aspect by ICD-10-CM leaves the AAAM's AIS as the only severity system without this feature, a feature which is vital for engineering use.

The various modifications to the AIS encompassed in AIS-85, AIS-90, NASS-88, NASS-93 and NTSB have been developed to satisfy the needs of their user groups. A unification of AIS data, and coordination with the other injury systems can only occur if the needs of all users can be satisfied within a unified system. Without satisfaction of user requirements, any new system will once again be subject to modifications by individual groups.

CONSIDERATIONS FOR A UNIFIED SYSTEM

From the study of the existing systems described above, the authors have identified key factors which are critical for the success of a unified system. The factors, in no particular order are:

1. To join the engineering and medical communities and unify AIS, NASS and NTSB, both **location** and **identification** features must be included. Location data from 20 to 24 main body regions has proved necessary for engineering purposes, with supporting **structure that allows computerized injury sorting by System, Structure, Organ, Lesion and Aspect**. Aspect is a key part of future databases currently missing from ICD-9, ICD-9-CM, AIS-85 and AIS-90. The location information must be included in a way that keeps the injury codes **defined uniquely** for clinical use.

2. The injuries described by the system must be **adequate in detail and coverage** to satisfy severity, impairment, mortality and reimbursement uses. Failing to include injury descriptions to cover each of these areas will result in "holes" in the system that prevent effective computerized interface with other major databases.

3. The system must be **"scalable"** so that it can be used at several levels. The simplest level, which might encompass a hundred codes or less, would be available for developing nations, and for

applications where detail is not important. The next level upward can include sufficient detail for engineering, mortality or reimbursement uses, with 2-3,000 codes. The highest level would be available for clinical uses and research and might contain 5,000 codes. Each level can "nest" or expand into the other, as depicted in Table 18.

4. The basic injury description and location information must be **independent** of the severity, impairment, charge or other factor that is coupled to the injury. This allows for periodic updates of the severity or impairment, an important consideration for clinical use. Conversely, the independence also allows users who wish to combine multiple years of data from multiple revisions to "normalize" the severity or impairment to a specified baseline by attaching the corresponding threat to life levels for the period desired.

Table 18.
Example of Injury Code "Nesting"

18 year old driver injured in MVC- found to have a swollen right ankle and difficulty walking.

Level of Detail	Injury Description
Low	Ankle fracture
Medium	Tibia fracture, NFS
Medium	Closed tibia fracture
High	Closed tibia medial malleolus fracture
High	Right closed & displaced tibia medial malleolus fracture

5. The system must be flexible enough to allow the inclusion of new injuries as the need arises. A formalized method is required to add new injury codes to the system and resolve the compatibility and historical data issues that added codes produce. The system must have the property of "**numerical consistency**" so that diagnoses can be counted at some level. The simplest level is counting injuries only by maximum severity by body chapter. A properly designed unified system can allow counting below the body chapter level by type of anatomic structure and specific anatomic structure, and in some cases perhaps individual codes. The property of numerical consistency thus accounts for the cases where one injury may in the future be counted as two or more injuries or vice-versa. Without rules and organization for numerical consistency corrections, trend studies can produce incorrect comparison counts of injuries.

6. Medical panels are needed to review and assign severity and impairment factors on a periodic basis to reflect changes in current medical technology, and organize and recommend new injury descriptions for inclusion.

7. The new system must have accompanying computerized "maps" to convert data from each of the current systems to the new system so that **no existing data is lost.**

8. **Overall scoring systems** (severity and presumably future impairment) such as MAIS, ISS and NISS, and their component variables should be integrated with the new system to make their calculation easy. These overall criteria would be normalized and adjusted as each review of the severity and impairment levels proceeds. In this way these tools stay "in sync" with the system in the future.

9. **Uniform interfaces** with other systems such as mortality and reimbursement.

10. The system needs the support and input from the **major data owners and users** in the US and around the world, and should be set forth as an international standard.

A UNIFIED INJURY SYSTEM (UIS)

The authors make the claim that a system with characteristics as outlined above is not only possible, but is both more desirable and less burdensome than the alternative. The alternative in this case is to allow the AIS, NASS and NTSB systems to go in their own directions with non-compatible revisions. This would lead to greater divergence of the NASS with the AIS, and as NASS is now the largest hand coded severity database in the world, it is likely NASS would become the engineering standard. The revisions to ICD-10 and ICD-10-CM will force another round of conversions from these systems, and these conversions will be more than likely written to NASS, not AIS, because AIS lacks aspect. Failure to develop a unified system would force the creation of a large set (20 or more) of additional, technically difficult conversions to allow comparison or trending of AIS, NASS, NTSB, ICD-10 and ICD-10-CM data.

The authors believe that the need, and benefit of a unified system is obvious. To demonstrate the feasibility of such a system they hope to produce a demonstration chapter of the new system for review in the near future.

CONCLUSION

The authors have presented a brief overview and examples of the codes used for many of the injury systems in both the United States and the world. The systems include two mortality systems, two hospital reimbursement systems, five severity systems and two impairment systems. None of the systems is directly compatibility with the others without electronic conversions or "maps". As the number of revisions of the systems grows, the number of maps required to analyze the data is becoming large. At the same time the trend toward the use of large statewide or national samples is causing more and more severity and impairment data to be created with maps. This trend makes the performance of the maps increasingly more important, and encourages the development of a unified system that would that enhance map precision.

Further, the increasing sophistication of research in the US and other countries is encouraging the collection of more complex injury information. At the same time, vehicle crashes are predicted to become major sources of economic expense in growing nations that require a simpler system for their use. A unified system that can satisfy both requirements is needed.

The authors propose a Unified Injury System (UIS) to satisfy both the engineering need for location information and the clinical need for detailed injury information for treatment. The system proposed is also "scalable" so that more detail can be used by clinicians, but the codes can be "collapsed" to a simpler level for use where the detail is not required.

Data created in past systems will be compatible with the UIS through the use of "maps" so no prior data will be lost. The linkages between the UIS system and the reimbursement and mortality systems can be improved to provide more accurate electronic conversion of hospital and mortality data.

Finally, the UIS separates the description and location of injuries from the threat to life, impairment, and reimbursement attributes. This allows the injuries to be collected and stored separately from these characteristics. Review boards (e.g. AAAM) can adjust the severity or impairment levels on a regular basis, and the injuries can be adjusted to correspond with the medical impairment level or severity level appropriate for either the present or a time in the past. This will permit trending, combining and comparison of injury severity and impairment over long time periods.

The authors believe that a unified system will greatly benefit clinicians, researchers and policy makers on a national and international level, and will allow the AIS severity system to reach a new level in use and acceptance.

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