Discussion document on injury severity measurement in administrative datasets

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Introduction

An expert working group meeting was convened by the National Center for Health Statistics (NCHS) on September 8-9, 2004 to discuss how best to measure injury severity based on information typically available in administrative datasets. The term 'administrative dataset' is used to differentiate it from a trauma registry dataset. While administrative data are used primarily for billing purposes and the data are usually abstracted and compiled by medical records personnel, these databases are also used for purposes other then billing, including surveillance, research, evaluating therapies and quality assurance. Trauma registry data, on the other hand, are generally considered the best source of in-depth data on the anatomic nature and physiologic consequences of injuries.(Rivara 2001; Wynn, Wise et al. 2001)

Given the current state of the art in severity scaling, discussions focused primarily on existing measures with a primary focus on threat to life while acknowledging the need to develop measures of threat to function and disability. The group discussed severity scales that are based on anatomical descriptions of the injury, focusing specifically on those based on the Abbreviated Injury Scale (AIS) (Gennarelli and Wodzin 2005) and the International Classification of Diseases (ICD) (World Health Organization 1992).

The following document is based on the presentations and discussions held at the 2-day meeting. It was agreed the contents will be reviewed as needed and during or following future expert meetings on this topic. We invite interested parties to provide comment to this discussion.

Why was the meeting convened?

NCHS convened this meeting to provide an in-depth discussion among experts on the feasibility of adding a measure of injury severity to its national administrative datasets to help monitor trends in injury incidence, and assess injury differences in population subgroups. Specifically, focus was on the National Hospital Discharge Survey with secondary emphasis on the ambulatory care surveys (NHAMCS-ED component) and the mortality data file.

Trends in injury hospitalization discharges and emergency department visits represent a mixture of at least two effects: 1) trends in the incidence of injury 2) trends in service utilization and service delivery. Because both can vary over time, it is not readily apparent whether changes in injury statistics observed using these injury indicators (eg trends in discharges or visits) reflect a trend in the incidence of injury. The incidence of injury would be better reflected by an indicator of the injury (e.g. injuries meeting a severity threshold) that is 'free' of extraneous factors like utilization and service delivery.(Cryer, Langley et al. 2002; Langley, Stephenson et al. 2003)

NCHS is also seeking assistance in devising a methodology for selecting a main injury from the multiple cause-of-death data so that U.S. data can be compared with data from countries that only have a "main injury" (e.g. assessing severity among injuries resulting in death). ICD-10 has provided no real guidance on how to select a main injury among multiple causes of injury mortality. [This issue was not followed up on to any great length and hence no consensus was reached. Comments are provided, however, in the section, 'next steps.']

NCHS would also like to promote the development and evaluation of scoring systems that predict residual impairment and functional limitations post-injury. Loss of function with potential disability is a major component of the burden of injury. Many of the established injury severity scaling techniques are primarily measures of threat to life. It is well recognized that these measures are not typically good predictors of threat to function or disability.

Injury Severity

Growth over the past two decades in the number and variety of injury severity scales reflects recognition that severity classification is critical for surveillance, epidemiological investigations and evaluations of programs and policies aimed at mitigating the impact of injury at both the individual and societal levels.(MacKenzie 1984; Rivara 2001) Injury severity generally describes the impact of an injury in terms of the extent of tissue damage (that is, the pathologic evidence of trauma) and/or the physiologic response of the body to that damage. Host factors known to mediate the effect of injury severity on outcome include age, gender, and the presence of certain pre-existing conditions, including intoxicants.

Since many of the early indices were initially developed for either patient triage or for use as covariates in evaluating the impact of services or systems on patient survival, these indices defined severity in terms of a "threat to life" criterion. Given the increased survival rates of trauma patients due to advances in injury control and emergency medical services, the scope of evaluation research has been broadened to include studies in which functional outcomes and disability are of increasing interest. As discussed below, current initiatives in severity measurement are focused on developing indices that measure these non-fatal outcomes. Interest has also been directed towards evaluating currently available indices (or developing new ones) for predicting consumption of health care resources and the associated costs.

This document focuses on two families of classifications have been used for much of the published work in this field and were the focus of the meeting: the Abbreviated Injury Scale (AIS) and the Clinical Modification of the International Classification of Diseases (ICD).

Abbreviated Injury Scale (AIS)

The AIS was introduced in 1971 and is in its 5th revision.(Gennarelli and Wodzin 2005) It is a specialized trauma classification of injuries based mainly on anatomical descriptors of the tissue damage caused by the injury. It was originally developed for use by multidisciplinary vehicular crash investigators in the 1970s as a standardized injury severity assessment tool. Subsequently, it gained acceptance with the trauma community for clinical research application. Currently, it is generally applied directly to records in specialized trauma registries. To this day, a large AIS-user population consists of non-clinical specialists in government (other than health agencies), academia and the automotive industry.

The AIS classification system was designed to distinguish between types of trauma of clinical importance as well as types of trauma of interest to vehicle designers and research engineers. It has been shown to provide a good basis for valid measurement of probability of death. The revisions to the classification of the injuries were also designed to provide a basis to support severity measures framed in terms other than probability of death, for example, probability of disability or functional impairment. However, to date, there has been little empirical data to support the notion that AIS does well in terms of probability of disability. Predicting functional impairment or disability was an important consideration in the 2005 Revision of the AIS classification system.

The AIS has two components: (1) the injury descriptor (often referred to as the 'predot" code) which is a unique numerical identifier for each injury description; and (2) the severity score (can be referred to as the 'post-dot' code). The severity score ranges from 1 (relatively minor) to 6 (currently untreatable), and is assigned to each injury descriptor. The severity scores are consensus assessments assigned by a group of experts and implicitly based on four criteria: threat to life, permanent impairment, treatment period, and energy dissipation. AIS values are considered to be well-ordered within body region, while there are documented discrepancies of the symmetry in scores between body regions (e.g. an AIS of 4 to the head may not be equal to an AIS of 4 to the extremities) (Clark and Winchell 2004) [and unpublished data based on analyses of NTDB- personal correspondence with Osler]

Injuries should be coded to the AIS by trained staff of trauma services or by specialists in injury data collection.   Assigning AIS scores based on medical records is time consuming; it is not routinely done outside of trauma centers.

The AIS is a severity measure for a single injury.   Many derivative severity scales have been developed to combine multiple injuries to create a single composite score for each patient including: Injury Severity Score (ISS)(Baker, O'Neill et al. 1974), The New Injury Severity Score (NISS)(Osler, Baker et al. 1997), the Anatomic Profile (AP) (Copes, Champion et al. 1990)and the Anatomic Profile Scale (APS)(Sacco, MacKenzie et al. 1999).

AIS is the most widely used severity score based on anatomic descriptors of injury; it is the official injury data collection tool of the National Highway Traffic Safety Administration (NHTSA) crash investigation teams. Although the reliability and validity of the AIS (and its derivatives for assessing the combined effect of multiple injuries) have been demonstrated, their utility for population-based research is limited due to the time it takes to assign adequate scores(MacKenzie, Shapiro et al. 1985).

International Classification of Diseases (ICD)

The ICD is a general purpose classification of diagnoses and related matters for all health conditions and includes diagnostic codes for both nature of injury and external causes of injury. The ICD does not incorporate an explicit severity dimension. The ICD is widely used to classify health conditions in the clinical, administrative, public health promotion, and research settings in the U.S. and abroad. The Barell Matrix is a framework for ICD-CM injury codes by anatomic region and type, but does not consider relative severity (Barell, Aharonson-Daniel et al. 2002) In the U.S., mortality data are currently coded using the 10^{th} revision of the ICD, ICD-10 (World Health Organization. 1992) and morbidity data are currently coded using the clinical modification of the 9^{th} revision of the ICD, ICD-9-CM. Due to its widespread use, there has long been interest in basing the assessment of injury severity on the ICD taxonomy.

ICDMAP

One approach for using the ICD for severity assessment has been the development of software called ICDMAP that translates ICD-9-CM coded discharge diagnoses into AIS pre-dot codes, injury descriptors, and severity scores (MacKenzie, Sacco et al. 1997). The software then uses the AIS severity scores to compute ISS, NISS, the components of the AP and the APS for the injured individual. The mapping does result in some loss of information due to differences in the injury classification systems. Resulting severity scores referred to as ICD/AIS scores are considered to be conservative measures of injury severity.

ICDMAP has been validated and shown to be useful in categorizing the severity of injuries when only ICD rubrics are available (MacKenzie, Steinwachs et al. 1989; Mullins, Veum-Stone et al. 1994; Clark and Winchell 2004). However, ICDMAP is becoming out of date; there is no map available for the updated ICD-9 CM, (or ICD-10) codes and there is no map to the AIS2005.

Both the AIS and ICDMAP are proprietary. This poses a major barrier for many potential users. There is a strong and growing consensus that both should be non-proprietary.

Furthermore, and often because of the proprietary nature of the AIS and its map to ICD, researchers have been developing empirically derived measures of severity based on ICD diagnoses and short term outcomes such as hospital mortality coded with ICD-9 CM. Although the development of such measures was attempted as early as the 1970s, (Levy, Mullner et al. 1978; Champion, Sacco et al. 1980) not until recently have we had sufficiently large enough databases and the statistical tools to develop and validate this approach to severity classification.

ICD-9 Injury Severity Score (ICISS)

One family of empirically derived measures of injury severity based on the ICD is the ICD-9 Injury Severity Score, referred to as ICISS. The development of this approach to injury severity assessment is on-going and shows great promise. For this document, the state of the development of the system as of the time of the meeting is described.

ICISS, first proposed by Osler and colleagues using the North Carolina Hospital Discharge Data, is based on the calculation of survival risk ratios (SRRs) for each ICD-9 CM code.(Osler, Rutledge et al. 1996; Rutledge, Hoyt et al. 1997) The SRR's are derived by dividing the number of patients that survive a given ICD-9 CM injury diagnosis code by the number of patients with that diagnosis code. ICISS, then, is the product of the SRRs corresponding to a patient's set of injuries. ICISS was shown to outperform several important competitors, including the Injury Severity Score which is based on the AIS (Hannan, Farrell et al. 1999; Sacco, MacKenzie et al. 1999; Meredith, Kilgo et al. 2003; Hannan, Waller et al. 2005).

There are several problems/issues with this early direct estimation approach that have been addressed:

1) SRRs are database-specific and it cannot be assumed that SRRs from one source will sustain accuracy and prediction in other sets of patients;
2) SRRs calculated in this manner are not independent and are contaminated by the presence of outcomes from other injuries in multiple trauma cases;
3) Interactions of injuries, which are known to exist, are not accounted for. That is, in some cases, two injuries may combine synergistically to produce a greater effect than the combination of the two acting independently. [This is equally likely to be a problem for scoring systems based on AIS and ICD.]

To address some of these concerns, Meredith et al. calculated SRR's from the National Trauma Data Bank and highlighted differences between these SRR's and the original set from NCHDD, underscoring the need for comparability when using SRR's from different sources. (Meredith, Kilgo et al. 2003) Other sets of SRR's have since been calculated from various trauma registries. Also, Meredith et al. calculated and described a set of independent SRRs that were derived from patients with only a single injury.(Meredith, Kilgo et al. 2003) These independent SRR's were shown to be better predictors of survival than their traditional counterparts. The accurate measurement and incorporation of injury interactions into trauma severity models has been elusive, though some alternatives have been proposed. (West, Rivara et al. 2000)

More recently, Kilgo et al. has shown that modeling a patient's most severe SRR rather than the full multiplicative ICISS score is more predictive of survival.(Kilgo, Osler et al. 2003) This "worst-injury" approach may be superior because most trauma patients are either so minimally injured as not to pose a direct threat to life or so severely injured that they cannot be saved. These cases compose approximately 97% of all trauma cases and the worst-injury approach does very well for these patients.

It could be argued that the SRR is exclusively an empirical observation of hospital survival given hospital admission, and lacks the independent descriptive value of AIS in terms of body system involvement. The SRR may therefore be less flexible for modeling outcomes other than hospital survival.

All measures of prediction (ICISS as well as methods based on AIS) are affected by the large proportion of deaths that occur before hospital admission as well as the large proportion of deaths in older patients that occur after hospital discharge. These probabilities will also change over time, and may be affected by extraneous factors like utilization and service delivery.

One major limitation in applying the ICISS to NCHS data is the dependence of the data on the system from which it was derived. ICISS scores could be derived from the NCHS National Hospital Discharge Survey. While the literature has shown that the ICISS can be internally valid, potential lack of external validity is often mentioned as a caveat. One study of interest to NCHS is the comparison of national level data from New Zealand and Australia showing both good external and internal validity (Stephenson, Henley et al. 2004). This study derived SRR's based on the Australian clinical modification of ICD-10 (ICD-10-AM) (Stephenson, Henley et al. 2004). In the United States, experts involved in its most recent revision of the AIS were consulted during the development of the injury chapter of ICD-10 CM. This is likely to improve both the ICDMAP software (should a new version be developed) as well as the ICISS measures of injury severity.

Severity and functional capacity/disability

Current severity scoring systems are inadequate for predicting non-fatal outcomes. AIS98 and its predecessor versions, for instance, have been shown to be inadequate for classifying injuries according to the probable degree of residual impairment or functional limitation. Injuries that are associated with high mortality but low morbidity (e.g., severe thoracic and abdominal injuries) are associated with high AIS scores whereas injuries associated with low mortality yet high morbidity and long term impairment (e.g., high energy, complex extremity fractures) are assigned relatively low values on the AIS (MacKenzie, Shapiro et al. 1986).

With increasing attention focused on the determinants and consequences of nonfatal injuries, several efforts have been made to develop a companion to the AIS that maps AIS injury descriptions into scores that better reflect the probable degree of functional limitations given the patient survives the injury. One such effort has been the development of expected or predicted functional capacity based on the Functional Capacity Index (FCI). These predicted FCI scores are referred to as $pFCI_{12}$ (AIS-90) (MacKenzie, Damiano et al. 1996; Segui-Gomez 1996; MacKenzie, Sacco et al. 2002).

The $pFCI_{12,}$ developed by MacKenzie et al, is a preference-based multi-attribute functional outcome measure designed for quantifying the impact of non-fatal injuries on function at 1 year post-injury. (MacKenzie, Damiano et al. 1996) The $pFCI_{12}$ predicts functional capacity across 10 dimensions of physical function. It is meant to predict the ability of the injured to perform tasks important for everyday living independent of physical and social environment. Dimension specific scores are assigned to each AIS injury description (the “pre-dots”) as is one overall score that summarizes function across the 10 dimensions. The overall FCI score ranges from 0 (representing death) to 1 (representing no limitations). The development of $pFCI_{12}$ values based on AIS injury descriptors greatly facilitates the use of existing population based data for adjusting potential life years and producing a measure of function-adjusted life years.

Predicted FCI scores were initially assigned to 1990 AIS injury descriptions. A validation of these predicted FCI showed some encouraging results. However, there were many injury patterns where the measured outcome (FCI) did not agree with the predicted outcome $pFCI_{12}$ (AIS-90) (Schluter, Neale et al. 2005) . The source of discrepancies is multifactorial, including inadequacies of the 1990 version of the AIS classification of injuries. In 2003 a group of experts was convened to re-assign $pFCI_{12}$ values to AIS2005 injury descriptions. To address the concern that some injuries can lead to variable outcomes, an “80% rule” was adopted. Using this rule, the $pFCI_{12}$ value expected of 80% of the cases was assigned to a particular injury. Given the changes made to both the FCI and the AIS as well as the improvement in our understanding of the nonfatal consequences of injuries, this exercise proved to be very successful, with full consensus reached for all assignments. However, before this new crosswalk between AIS and $pFCI_{12}$ can be widely used, the revised $pFCI_{12}$ (AIS) values must be validated.

ICISS could be used to construct empirically derived measures of severity based on non-fatal outcomes. Although some work is underway to develop such measures based on resource consumption (e.g. length of stay, intensity of care) and short term morbidity (e.g. hospital complications), there is no database currently available that is large enough and representative enough to be used in developing an ICISS-like measure for predicting functional outcomes or disability. Furthermore, the ICD-CM classification has not been evaluated to determine if the injury descriptions are detailed enough to differentiate between injuries resulting in non-fatal outcomes. In addition, although resource use is important, it may not accurately reflect patient outcome. The routine administrative medical record data needs to be evaluated to determine if there is enough detail to use a classification such as the International Classification of Functioning, Disability and Health (ICF) to measure disability or how to ensure that codes were being applied and interpreted uniformly.

RECOMMENDATIONS

The Expert Panel had presented a range of views, at times conflicting, about the direction in which NCHS and the field more generally should be heading. The list below has the major themes which emerged from the meeting. The list is in no order of priority and is not intended to imply consensus by those attending the meeting. Its presentation is intended to provide some guidance and facilitate further discussion and debate as we attempt to evaluate methods for improving the measurement of injury severity especially in the context of large administrative databases.

1. AIS and the ICD/MAP should be **maintained and updated**. It should be **non-proprietary.** At the current time, the process for seeing to this is underway. The AIS is useful for trauma center evaluation and quality improvement. In addition, the AIS2005 should be particularly useful for classifying injuries according to expected functional outcomes, using the $pFCI_{12}$. Currently, it is the only way that functional limitation/ disability can be predicted from injury. Once ICDMAP software is updated to reflect

changes to both ICD-9-CM and AIS2005, it should be re-evaluated for its predictive validity.

2. For use with national and sub-national administrative data meeting certain minimum requirements (e.g. size of dataset, minimum number of deaths, etc), ICISS (that is, assigning severity based on observed hospital survival for a single ICD code or group of codes or multiplying the "SRRs" for multiple injuries) is a useful alternative to the current, non-updated mapping of ICD to AIS and its derivatives. This recommendation is based on the fact that ICISS scores are empirically derived and recent studies have shown the ICISS to perform better than the ISS, NISS and APS scores derived from the current version of the ICDMAP. (Hannan, Farrell et al. 1999; Sacco, MacKenzie et al. 1999; Meredith, Kilgo et al. 2003; Hannan, Waller et al. 2005) Nonetheless, it is noted that while ICISS has been "shown to outperform" other methods, statistical tests of "performance" are imperfect, comparisons have been limited to hospital survival, and measured differences may be of questionable epidemiologic significance.

3. At this point in time, it appears that prediction of death modeled using the lowest SRR (i.e. worst recorded injury diagnosis) is better than ICISS based on all diagnoses (Kilgo, Osler et al. 2003)

4. The Clinical Modification of ICD-9 should continue to be updated in the US until ICD-10-CM is implemented. The committee strongly recommends that the introduction

of the ICD-10-CM in the U.S. be expedited. The specificity in injury classification in 10th revisions should improve the predictive abilities of the ICISS and ICDMAP.

5. The application of an injury severity measure based on the clinical modifications of the ICD to the mortality data to facilitate the selection of a main injury from multiple causes of death needs further exploration. In the U.S., for the minority of injury deaths in which more than one injury diagnosis is listed, measures of severity of the injuries could be used in the decision paths to choosing a main injury.

6. Resources should be directed to the further development of injury classifications that identify complications and functional impairment. Work in New Zealand has shown that a fruitful line of investigation is likely to be around the development of indicators based on threat-of-disablement severity measures, or which reflect burden of injury as measured by cost. For this to proceed, however, diagnostic data needs to be improved and work needs to be done to identify thresholds for ‘serious’ disablement that avoid the biasing influence of extraneous factors on trends.(Cryer, Langley et al. 2004)

NEXT STEPS

The working group should continue formal and informal discussions, reread the background materials that were distributed, review more recent literature (Sharma 2005) talk with other colleagues, develop and test new hypotheses and methods, and reconvene, if possible, in the Fall 2005.

Inform potential users of the ICISS of the availability of relevant datasets: National Hospital Discharge Survey (NHDS); National Hospital Ambulatory Medical Care Survey – Emergency Department component (NHAMCS-ED); National Trauma Data Bank (NTDB), the Health Care and Utilization Project (HCUP), the Medical Expenditure Panel Survey (MEPS) etc. States with access to linked inpatient and outpatient datasets should consider record linkage to get a more complete picture of the injured population.

Provide additional/supplementary documentation for these files to facilitate their use for injury severity measurement research, development and reporting.

Decide: What covariates to include in the derivation of SRR's: ie, none vs. age, sex, injury etiology, mechanism of injury, co-morbidity, etc.

Encourage further cross-fertilization between AIS and ICD by, for example, implementing in each of these classifications, components of the other that have been shown to be more effective for injury severity measurement

Decide on definition of a trauma patient. If SRR's are derived from a data set with all trauma patients, the values could be quite different than if they are derived from a data set of seriously injured trauma patients (based on some definition, e.g., it is roughly an ISS greater than or equal to 9 in NY's registry).

Concerning NCHS publications and public release data

Develop a table of SRR's and ICDMAP-2005 scores for the ICD-9 CM injury diagnoses contained in several years of NHDS and include them on the NCHS-Injury website (www.cdc.gov/nchs/injury.htm), including an explanatory document allowing users to choose which method of risk adjustment they prefer to use. The SRR's are readily able to be produced. AIS scores will entail updating ICDMAP to reflect both updates to ICD-9 CM as well as updating AIS to AIS98 and then to AIS2005. [This will require additional funding.]

Tasks to achieve this are:

1. Choose / produce a suitable SRR set. Considerations are: type of data set from which to derive SRRs (trauma service data vs more-or-less representative set of all hospitalized injuries); whether to derive "simple" SRRs based on all cases, or "independent" SRRs based on single-injury cases, or SRRs adjusted by statistical means for best fit..

2. Choose one among the available variations of ICISS method (ie based on lowest SRR or all SRRs)

3. Decide whether to add calculated ICISS values to the public-release NHDS data file, or to develop and release software with which interested users can calculate ICISS values, or both.

4. Develop and release documentation of the ICISS method as applied to the NHDS public release file.

COMMENTS INVITED

Please send your comments to Chairperson, Lois A. Fingerhut. The comments will be collated and distributed to the group for review.

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