Has TRISS become an anachronism? A comparison of mortality between the National Trauma Data Bank and Major Trauma Outcome Study databases

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Author Disclosures: All authors have nothing to disclose.

Reviewer Disclosures: Adam Shiroff, MD, speaker honorarium, Synthes. Howard Champion has nothing to disclose.

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Submitted: November 28, 2011; Revised: February 7, 2012; Accepted: April 9, 2012.
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This study was presented at the 25th annual meeting of the Eastern Association for the Surgery of Trauma, January 10–14, 2012, in Lake Buena Vista, Florida.
These data were provided by the Pennsylvania Trauma Systems Foundation, Mechanicsburg, Pennsylvania. The Foundation specifically disclaims responsibility for any analyses, interpretations, or conclusions.
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DOI: 10.1097/TA.0b013e31825a7758

BACKGROUND: The Trauma and Injury Severity Score (TRISS) has been the approach to trauma outcome prediction during the past 20 years and has been adopted by many commercial registries. Unfortunately, its survival predictions are based upon coefficients that were derived from a data set collected in the 1980s and updated only once using a data set collected in the early 1990s. We hypothesized that the improvements in trauma care during the past 20 years would lead to improved survival in a large database, thus making the TRISS biased.

METHODS: The TRISSs from the Pennsylvania statewide trauma registry (Collector, Digital Innovations) for the years 1990 to 2010. Observed-to-expected mortality ratios for each year of the study were calculated by taking the ratio of actual deaths (observed deaths, O) to the summation of the probability of mortality predicted by the TRISS taken over all patients (expected deaths, E). For reference, O/E ratio should approach 1 if the TRISS is well calibrated (i.e., has predictive accuracy).

RESULTS: There were 408,489 patients with complete data sufficient to calculate the TRISSs. There was a significant trend toward improved outcome (i.e., decreasing O/E ratio; nonparametric test of trend, $p < 0.001$) over time in both the total population and the blunt trauma subpopulation. In the penetrating trauma population, there was a trend toward improved outcome (decreasing O/E ratio), but it did not quite reach significance (nonparametric test of trend $p = 0.073$).

CONCLUSION: There is a steady trend toward improved O/E survival in the Pennsylvania database with each passing year, suggesting that the TRISS is drifting out of calibration. It is likely that improvements in care account for these changes. For the TRISS to remain an accurate outcome prediction model, new coefficients would need to be calculated periodically to keep up with trends in trauma care. This requirement for occasional updating is likely to be a requirement of any trauma prediction model, but because many other deficiencies in the TRISS have been reported, we think that rather than updating the TRISS, it would be more productive to replace the TRISS with a modern statistical model. (*J Trauma Acute Care Surg*. 2012;73: 326–331. Copyright © 2012 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Prognostic study, level II.

KEY WORDS: TRISS; NTDB; MTOS.

Medical professionals during the past decades have expressed the need for a systematic method of evaluating trauma care, particularly in the form of a standardized scoring system. A reliable trauma severity scoring mechanism could provide many benefits, including facilitation of better field triage and more reliable prediction of individual outcome.[1,2] Furthermore, the creation of a patient scoring database could act as an important resource in therapeutic resource allocation efforts.[2] In addition, this data could prove useful for quality improvement and trauma assessment programs, leading to advancements in trauma care.[3] Most notably, an encompassing trauma severity score could provide the tools for benchmarking and monitoring of traumatic injury outcome through time, between hospitals, and over regions.[4,5]

Multiple injury severity scales were developed in the 1970s and early 1980s to address different injury characteristics and parts of the body. The most well known of these scoring systems include the Glasgow Coma Scale (GCS), Trauma Index, Trauma Score, Abbreviated Injury Scale (AIS), Revised Trauma Score (RTS), and Injury Severity Score (ISS).[1,2,6,7] The Trauma and Injury Severity Score (TRISS), created by Champion et al. in 1983,[2] used a logistic regression approach to determining probability of survival, combining measures concerning anatomy (ISS), physiology (RTS), age, and mechanism of injury (MOI) to create a single prediction of survival.[5] The TRISSs range from 0 (certain death) to 1 (certain survival).[8] The formula is as follows:

$$\mathrm{Ps} = 1/(1 + \mathrm{e}^{-\beta})$$

$$\beta = \beta_0 + \beta_1(\text{ RTS}) + \beta_2(\text{ ISS}) + \beta_3(\text{ Age})$$

The coefficients $\beta_0 - \beta_3$ are derived from multiple regression analysis, and they differ for blunt and penetrating traumatic injuries. They were originally estimated from ordinary logistic regression models when the TRISS was first created, and then were revised in 1995 through multiple regression analysis of the Major Trauma Outcome Study (MTOS).[9]

The TRISS ushered in a new era of outcome prediction, in which the trauma community led the way, compared with other medical specialties. The TRISS has been the most commonly used tool in benchmarking trauma outcome, judging hospital performance, and monitoring mortality rates.[4,10,11] It has remained the standard method for traumatic injury severity assessment and adjustment for severity in patient population comparisons.[12] However, the coefficients $\beta_0 - \beta_3$ remain based on MTOS data collected between 1982 and 1987[5] or updated in 1990[8] and 1995.[5,8,9] In this study, we sought to determine whether trauma mortality rates have changed significantly since that time and to examine the effects of these potential alterations on the reliability of the TRISS predictive survival probabilities. We hypothesized that with improvements in trauma care, over time, the predictive accuracy of the TRISS would decrease because the TRISS is calculated from regression coefficients from a database of trauma patients who had their care in the late 1980s.

MATERIALS AND METHODS

In the first part of this study, mortality rates of two databases were compared: the MTOS from 1982 to 1987, and the National Trauma Data Bank (NTDB) data from 2002 to 2006 (as a snapshot of how trauma care has changed/improved over the years). The patient population of each database was stratified for mortality versus age, comparing 5-year age increments. The mean (95% confidence interval [CI]) was included for each 5-year interval in both databases. Odds ratios (95% CI) were compared between databases and stratified based on age groups using the Mantel-Haenszel test. We attributed significance to $p < 0.05$.

TABLE 1. Recalibrated Coefficients of the MTOS

Blunt		Penetrating	
b_0	−0.4499	p_0	−2.5355
b_1 (RTS)	0.8085	p_1 (RTS)	0.9934
b_2 (ISS)	−0.0835	p_2 (ISS)	−0.0651
b_3 (age*)	−1.7430	p_3 (age*)	−1.1360

For the second part of the study, with permission from the Pennsylvania Trauma Systems Foundation (PTSF), we obtained all of the basic data elements (age, RTS, and ISS), as well as blunt versus penetrating and live/die from their statewide trauma registry (Pennsylvania Trauma Outcome Study [PTOS] registry; Collector, Digital Innovation, Baltimore, MD). The PTOS database is a population-based statewide trauma registry that includes data on all patients admitted with traumatic injuries to accredited trauma centers in Pennsylvania, meeting PTOS inclusion criteria as follows: admission to the intensive care unit or step-down unit, hospital length of stay greater than 48 hours, hospital admissions transferred from another hospital, and transfers out to an accredited trauma center.[13] The PTOS database includes de-identified data on patient demographics, AIS-90 codes and DRG International Classification of Diseases—9th Rev.—Clinical Modification codes, MOI (based on DRG International Classification of Diseases—9th Rev.—Clinical Modification Ecodes), comorbidities, physiology information, MOIs, in-hospital mortality, in-house complications, transfer status, processes of care, and encrypted hospital identifiers. Steps to insure data quality in the PTOS registry include the use of standard abstraction software with automatic data checks, a data definition manual, and internal and external data auditing.[13] Probability of survival (Ps) was estimated for the entire data set using the coefficients published in 1995 by Champion et al.[9] in a logistic model of the form:

$$Ps = 1/(1 + e^{-\beta})$$

where e = 2.718282 (base of Naplerian logarithms), $d = b_0 + b_1$ (RTS) + b_2 (ISS) + b_3 (age*) (for blunt injuries) or $d = p_0 + p_1$ (RTS) + p_2 (ISS) + p_3 (age*) (for penetrating injuries), RTS is measured on emergency department admission, age* = 1 if patient is 55 years or older, age* = 0 if patient is younger than 55 years, and b_0, b_1, b_2, and b_3 (or p_0, p_1, p_2, and p_3) are regression coefficients.

The coefficients used to calculate Ps in this study were the 1995[9] recalibrated coefficients of the MTOS shown in Table 1.

A complete case analysis method was used to deal with missing data points. Patients with burn and 73,455 pediatric patients (<16 years) were excluded from the analysis, as were 11,762 patients who received paralytic agents and were recorded as having a respiratory rate of zero because using this iatrogenically depressed respiratory rate in the computation of the TRISS produces an inaccurately depressed prediction of survival. Observed-to-expected mortality ratios for each year of the study were calculated by taking the ratio of actual deaths (observed deaths, O) to the summation of the probability of mortality predicted by the TRISS taken over all patients (expected deaths, E).

RESULTS

Part 1

There were 80,544 patients in the MTOS data set and 1,912,952 patients in the NTDB data set. Overall mortality was 9% for MTOS versus 4.4% for NTDB. Execution of the Mantel-Haenszel test found a significant difference in overall mortality (p < 0.001) between the MTOS and NTDB study groups. When comparing individual age groups, the odds ratio (Table 1) and CIs for all except for the age group 85 years to 89 years were less than 1. This suggests that the NTDB data set has significantly lower mortality rates than the MTOS data set in all but the age group 85 years to 89 years (Fig. 1). When we noted the striking disparity in mortality from the original MTOS database during the course of more than 20 years, we wondered how this might affect the TRISS, which had been using the same coefficients for the past 15 years. This prompted the second analysis of this study.

Part 2

There were 451,868 patients admitted to the PTSF database for the years 1990 to 2010. Of these, 9.6% of the total patients (of whom 17.6% happened to have died) had missing values such that the TRISS could not be calculated. Figure 2 demonstrates the O/E mortality ratio for the entire cohort over time. There was a significant trend toward improving outcome (i.e., fewer patients died than were expected to) as time progressed during the time frame of this study. Figures 3 and 4 demonstrated the O/E ratio versus time for blunt and penetrating trauma, respectively, but this trend seems to be due more to improved survival of patients with blunt injury (Fig. 3) than of patients with penetrating injury (Fig. 4).

DISCUSSION

Although the TRISS has been in the vanguard of trauma outcome scoring and has been a mainstay of most trauma registries during the past 20 years, this study shows that the accuracy of outcome prediction has drifted further out of calibration with each passing year. When one uses a fixed set of

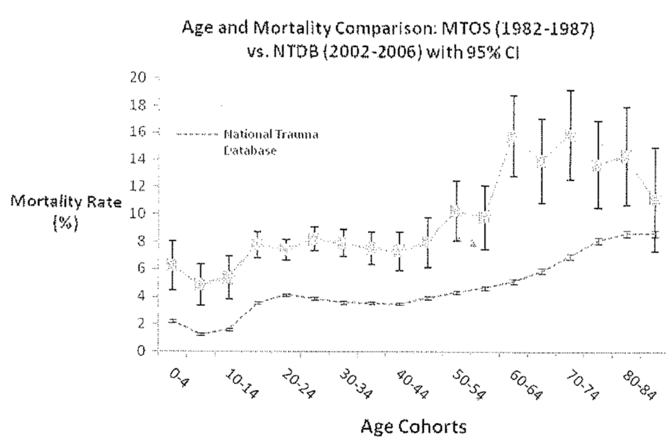

Figure 1. Age and mortality comparison. MTOS (1982–1987) versus NTDB (2002–2006) with 95% CI.

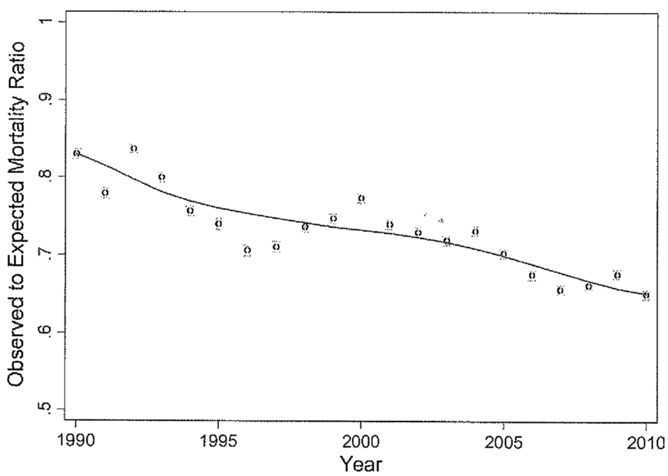

Figure 2. O/E ratio of all 451,868 patients over time (nonparametric test of trend, $p < 0.001$).

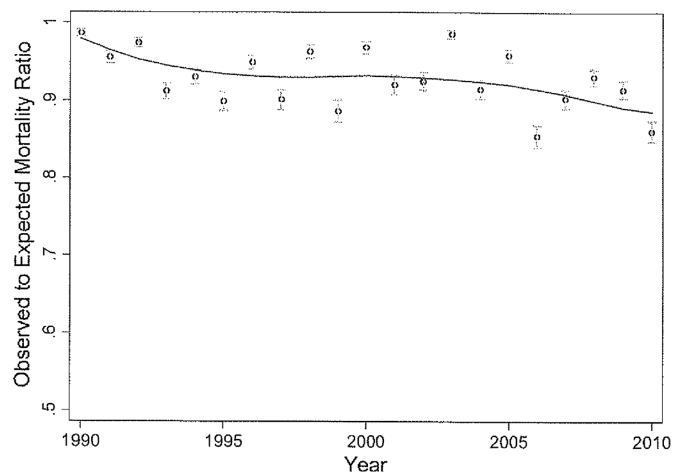

Figure 4. O/E ratio of 47,933 patients with penetrating trauma over time (nonparametric test of trend, $p = 0.073$).

coefficients for the TRISS calculation from a database of patients that is many years old, the O/E ratio steadily improves as each year passes. We think that this decrease in O/E mortality ratio reflects an improvement in trauma care over time that benefits the patients by an improved survival. This is evidenced by the snapshot graph of mortality in an older (MTOS 1987) database versus a more current (NTDB 2002–2006) in which the mortality was more than two times as high in the older database relative to the current one (MTOS, 9%; NTDB, 4.4%). In a well-calibrated outcome prediction model, the O/E ratio should be close to 1. In the PTSF data set, one can observe that there is a steady decrease in the O/E ratio over time, which we think is caused by improvements in trauma care that positively impact survival. It is interesting to note that the drift in calibration for O/E ratio over the years was more striking in the blunt trauma population rather than the penetrating trauma population. It is unclear what the reasons are for these differences except for the possibility that there have been more significant changes in the management of patients with blunt trauma over the years compared with patients with penetrating trauma.

One might argue that one simply needs to provide coefficients from more recent databases to derive more accurate the TRISSs. This has been done by several investigators. A 2004 study conducted by Millham et al.[12] sought to determine the accuracy of the TRISS as a predictor of mortality and the potential of creating more up-to-date coefficients to increase the scoring system's predictive abilities. Using 121,527 records from the 1994 to 1997 NTDB data, Millham et al. tested the TRISS accuracy in mortality prediction and also calculated new coefficients to test on this same data set. The authors determined that although the traditional the TRISS equation had a limited ability to predict trauma patient survival, prediction accuracy was markedly improved with updated coefficients. More recently in 2009, Schluter et al.[14] similarly attempted to revise the TRISS coefficients in an effort to increase prediction abilities and had similar determinations. These researchers used both the NTDB and National Sample Project (NSP), a nationally representative sample of patients with trauma, to generate new coefficients and compare predictive performances of these new coefficients with those created from MTOS data in 1995.[14,15] Area under the curve analysis determined that both NTDB- and NSP-derived coefficients' discrimination abilities were not significantly different from those of the MTOS-derived coefficients. Nevertheless, the authors recommended that their new set of coefficients based on the NTDB be adopted for official use by trauma registries.[14] This recommendation has yet to be adopted. What we have shown in our study is that the O/E mortality ratio steadily dropped in the PTSF database, and as such, to maintain calibration, new coefficients should be derived periodically to maintain accuracy of the TRISS. The limited shelf life of the TRISS coefficients represents a serious, but manageable, problem. However, there are other, more serious problems with the TRISS. Many articles have considered the impact of missing data on the TRISS coefficients.[3,4,9,11,14,15] The TRISS coefficients have typically been derived from data of those patients with no missing information because the TRISS can

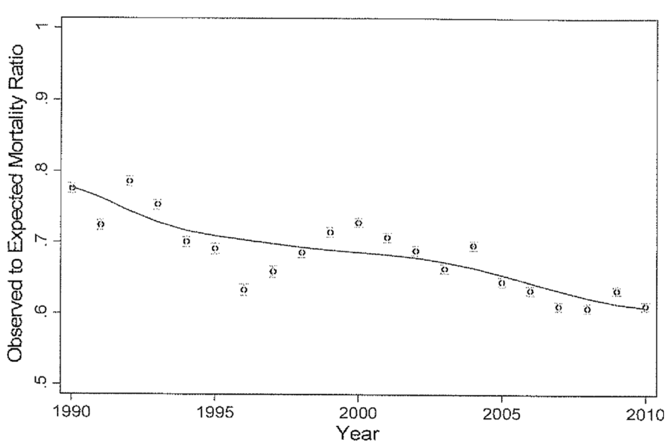

Figure 3. O/E ratio of 403,935 patients with blunt trauma over time (nonparametric test of trend, $p < 0.001$).

only be calculated if no pertinent measure (RTS, ISS, age, and MOI) is missing for a patient. Patients with missing information have been shown more likely to die, thus skewing the representativeness of the calculated coefficients.[11] In more recent databases, the level of missing data has increased substantially; whereas the MTOS only had 11.3% missing data, and NSP has 22.4% missing data.[10] Even in the study reported herein, 9.6% of patients from the PTSF database had to be excluded because of missing data points. Incomplete data exclusion is a major issue that must be addressed if the TRISS is to become a more accurate predictor of mortality. Statisticians have used imputation to account for missing data in the TRISS, but results depend heavily on the details of the imputation technique and models used.[4,11,12,15,16] Moreover, imputation attempts to date have depended upon missing data being "missing at random," a very strong assumption that, although unverifiable, is unlikely to be true in trauma data sets.[17] Most databases (including the PTSF) have more TRISS prediction data missing for patients who die than for surviving patients. These missing data are a particularly vexing problem because it is precisely the patients that we are most interested in that have been excluded from the TRISS scoring.

The TRISS also has significant technical, as well as practical, shortcomings as a statistical model. The TRISS assumes that both ISS and RTS are linear in the log odds of survival, which seems not to be true.[15] In addition, the categorizations applied to the individual predictors in the RTS (systolic blood pressure, respiratory rate, GCS) were assigned many years ago primarily based upon clinical intuition and are unlikely to be mathematically optimal. In addition, the TRISS fails to account for interactions among predictor variables.[15] It has also been suggested that the addition of other variables, such as comorbidities, would increase the accuracy of the TRISS.[3,7] As a practical matter, the physiologic measures of RTS are inherently unstable.[11] Because RTS is calculated using the first values recorded at admission to the hospital, it is heavily influenced by out-of-hospital care received by the patient.[11] Finally, and perhaps most problematically, the single most important predictor variable in the TRISS, GCS, cannot be accurately assigned (and may not be defined) for many of the patients who are most gravely injured, such as those who are intubated.

In an attempt to address the shortcomings of their scoring system, Champion et al. introduced A Severity Characterization of Trauma (ASCOT) in 1990 as an improvement over the TRISS. It uses Anatomic Profile instead of ISS, stratifies age into five distinct ranges, and excludes outlying patients from the logistic regression model.[1,3] A 1992 study by Markle et al.[16] compared the TRISS and ASCOT accuracy in survival prediction using the Institute for Trauma and Emergency Care database, which included 5,685 patients from eight New York Medical College–affiliated hospitals. The authors noted a relatively small gain in predictive accuracy with ASCOT over the TRISS, but this was offset by the complexity of ASCOT. A study by ASCOT creators Champion et al.[3] comparing the TRISS and ASCOT found that ASCOT outperformed the TRISS in predicting both patients with blunt trauma and patients with penetrating trauma.[1] Although some of these studies found a marginal gain in predictive accuracy with ASCOT, the improvement was not enough to warrant the complexity of Anatomic Profile calculations and the increased computer processing needs of ASCOT, and thus, the TRISS has remained the most widely used trauma outcome prediction method.

Several authors have attempted to rehabilitate the TRISS using various statistical methods. Osler et al.[18] found improved calibration of the TRISS by using the quadratic function of the ISS term. Schluter[15] found improvements in the predictive power of the TRISS by reclassifying variables in groups and treating the variable categories nominally. Included in these efforts would be aforementioned ASCOT[3,15] and the imputation techniques various authors have used.[14] None of these efforts have been adopted in any widespread way. We think that this is caused by the underlying fundamental problems with the TRISS (missing variables, failure to appropriately transform predictors used in the logistic model, confusion over how to classify variables [i.e., GCS of intubated patients, GCS of patients who receive muscle relaxants], use of DRG International Classification of Diseases—9th Rev. codes to generate ISS scores, and changing coefficients with time) are preventing the TRISS from being the outcome predictor of the future.

We think that an entirely new outcome prediction model needs to be developed. Hemmila et al.[19] developed a new outcome prediction model as part of a new rigorous benchmarking outcomes process for trauma centers called Trauma Quality Improvement Program. The outcome prediction model used in Trauma Quality Improvement Program looks remarkably similar to the TRISS, with some novel improvements (such as using only the motor components of the GCS) but unfortunately reduced the information in most continuous predictors (Glasgow Motor Score, systolic blood pressure, ISS, age, pulse, MOI, etc.) by their dichotomization. One of the fundamental principles of modeling is to never dichotomize a continuous variable because this loses information.[20]

With the growing public demands for benchmarking and outcome data, now is the time to get all the important players in the room and develop a new, more accurate scoring model. This new model should

1. Have fundamentally sound statistical underpinning. That is, all predictors should be carefully specified in the logistic model to ensure linearity in the log odds of mortality.
2. Minimize missing variables by using only predictors that are reliably defined and available. Models must have variables that can be collected reliably (such as the Glasgow Motor Score rather than the entire GCS, or using AIS-2005 to calculate ISS).
3. Be able to accommodate improvements in trauma care and maintain accuracy. To do this, there should be a clear mechanism for periodic updating of the model. Possibly a committee of experts with acknowledged gravitas, such as the American Association for the Surgery of Trauma Injury Assessment and Outcome Committee, could take on this task.

We continue to use the TRISS, a predictive model that is proven to have relatively poor predictive ability. Although a myriad of studies have examined different ways in which to improve this scoring system, the medical community is yet to find a solution satisfactory enough to warrant changing the system. As academics continue to consider possible solutions to this increasingly urgent problem, we suggest paying particular attention to increasing coefficient accuracy, addressing effects of missing data, considering possible better statistical models, and testing different ways of representing anatomic and physiologic characteristics. As trauma care continues to become more nuanced and mortality rates continue to decrease, the importance of a reliable predictive outcome model only increases.

AUTHORSHIP

F.B.R. and T.M.O. designed this study. N.M. acquired the data, which T.M.O. and M.A.H. analyzed. F.B.R. and M.K. prepared the manuscript. T.M.O., A.R., E.H.B., J.C.L., and D.W. participated in editorial review.

DISCLOSURE

These data were provided by the Pennsylvania Trauma Systems Foundation, Mechanicsburg, Pennsylvania. The foundation specifically disclaims responsibility for any analyses, interpretations or conclusions. The authors declare no conflict of interest.

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EDITORIAL CRITIQUE

This work is timely. It challenges the value of TRISS as the method for risk adjustment in trauma care. This analysis is needed, particularly when we take into consideration that TRISS was derived from a population of patients cared for between 1982 and 1987. Survival estimates reflect care provided at that time. However, I think there is universal agreement that trauma care has changed and mortality has improved significantly over the interval between 1987 and 2012. For this reason alone, we should not be comparing today's outcomes to yesterday's patients. However, when we review the manuscript in detail, several questions arise.

First, the authors compared age-stratified mortality rates between the MTOS and the NTDB with patients cared for about twenty years apart and demonstrated that mortality in the NTDB is lower. However, mortality might be lower because injury severity is lower due to differences in case ascertainment. For example, MTOS required inclusion of all hospital admissions due to trauma or all injured patients admitted to intensive care. NTDB over the years, 2002 to 2006, used whatever the hospitals provided. This limitation could be overcome by stratifying the survival by some measure of injury severity(e.g. ISS).

Second, there is a significant amount of missing data. Patients with missing data had a higher mortality rate than patients without missing data, yet were dropped from the analysis. If rates of missing data increased over time, this might entirely explain the results. Why not impute the missing data?

What was particularly interesting were the differences in mortality over time in patients with blunt injury, but less so with penetrating mechanisms. While it is possible that care has improved more so for one population than another, it is also plausible that better injury ascertainment with increasing use of CT scan (particularly for blunt injury) over the last twenty years might account for the difference. There might be no material difference in outcome, we just identify injuries to a greater extent, increasing the ISS so for a given injury severity mortality is lower.

In spite of these limitations, this work demonstrates that the trauma community needs to evolve. We need to standardize how we manage risk adjustment, what we do with missing data and how we code injuries (there is a tremendous variability in injury coding across centers). We also need to pay a little more attention to the data populating our registries. Quality improvement, even for data, begins at home.

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