**Systematic Review of Published Evidence Regarding Trauma System Effectiveness**

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**Objective:** Provide a systematic review of the published literature assessing the affect of trauma center/system implementation on patient outcomes.

**Data Sources:** A bibliographic search of MEDLINE (1966 - May of 1998), HealthSTAR (1995 - May of 1998), and CINAHL (1982 - May of 1998). Additional manuscripts were identified in the references of reviewed manuscripts. Literature was limited to English language reports on trauma systems in the United States and Canada.

**Study Selection:** Initial inclusion criteria were based on methodologic criteria (i.e., a comparative [controlled] study). Authors independently assessed the strength of evidence demonstrated by each article.

**Data Extraction:** Included articles were classified into three groups based on study design: panel review studies, trauma registry comparison studies, and population-based studies. Key demographic, sampling frame, study design, and outcome variables were tabulated for each included study. Potential sources of bias were also identified and tabled.

**Data Synthesis:** A total of 12, 11, and 17 studies were incorporated into individual evidence tables for panel review, registry comparison, and population-based studies, respectively. Included studies rely on weak evidence (Class III) to assess the impact of trauma systems on patient care and outcome.

**Conclusions:** To date, studies assessing trauma system efficacy rely on hospital deaths as the primary indicator of effectiveness. Future research should use more sophisticated study designs (Class II) and expand available outcome measures to assess the entire continuum of care, including prehospital, rehabilitation outcomes, and long-term quality of life.

**Key Words:** Mortality; Evidence report; Trauma systems.

**INTRODUCTION**
Burden of Injury

The actual impact of injury on the lives of US citizens is difficult to quantify because mortality is frequent among younger populations and disability caused by injury is often long lasting. For example, although injury is the fourth leading cause of death in the United States, life-years lost are greater from injury than from the three other leading causes of death combined (i.e., heart disease, cancer, and stroke). Injury causes, on average, 36 life-years lost per death compared with 12 years for heart disease and stroke combined, and 16 life-years lost for cancer.1 2

A recent report prepared for the United States Congress by The Centers for Disease Control attempted to document the long-term burden associated with injury in the United States.3 Based on 1985 data, the report estimated that 57 million persons were injured in the United States at a lifetime direct cost to the nation of $156.6 billion (1985) dollars. As a result of the injuries occurring in 1985, 155,665 persons died (142,568 deaths in 1985 and 13,097 deaths in subsequent years). An additional 2.3 million persons were hospitalized for their injuries, whereas 54.4 million persons were treated outside the hospital for injuries that required restricted activity for more than or equal to 1 day. Morbidity losses included 5.1 million productive life-years lost, or 9 productive life-years lost per 100 injured persons.

Implementation of Systematic Trauma Care

In response to alarming morbidity and mortality rates associated with injury, efforts emerged to systematize the application of optimal emergency trauma care. Early publications provide case series narratives of ill-coordinated, substandard trauma care that resulted in death.4 5 Subsequent work attempted to quantify improvement to trauma care through enhanced emergency medical services training and triage,6 advances in hospital procedures and training,7 and the organization of coordinated in-hospital trauma care teams.8 A natural extension of this body of knowledge was the formalization of trauma systems. Trauma systems were designed to "facilitate and coordinate a multidisciplinary system response to severely injured patients from the time of injury through the provision of definitive care."9 10

The subsequent literature directed at assessing the effectiveness of trauma systems is diverse, crossing several disciplines. Study designs, case definitions, and analytical procedures vary greatly across studies, making it difficult for health care professionals or administrators to synthesize the information and make informed decisions regarding trauma system implementation and maintenance.

Formulation of a Consensus Conference

In July of 1998, a symposium was organized to bring together health care professionals from various medical and academic fields to critically review the current published literature regarding trauma system effectiveness. In preparation for the symposium, a comprehensive review of the literature was conducted and selected articles assessing trauma center/system effectiveness were summarized into draft evidence tables and mailed to persons registered to participate in the symposium. These preliminary evidence tables are published elsewhere.11 The purpose of this article is twofold. First, this manuscript formally documents the process used to identify, classify, assess, and compile the published evidence regarding the effect of trauma centers/systems on patient outcomes. Second, this article documents the strength of evidence demonstrated by studies contained in the finalized evidence tables that resulted from a formal critique at the symposium.
METHODS

Literature Retrieval

The published literature assessing trauma system effectiveness was identified by using an electronic search of MEDLINE (1966 through May of 1998), HealthSTAR (1995 to May of 1998), and CINAHL (1982 to May of 1998). The search string constructed to identify the appropriate literature involved exploding the keyword terms "trauma center" and "trauma system." Exploding these terms incorporated published literature that made mention of "health services research," "wounds and/or injuries," or "regional medical programs" in the keyword list or in the abstract. This type of search strategy is known to maximize the sensitivity of the search while compromising the specificity of the search. Additional manuscripts were identified by hand-searching citations listed in articles previously identified by the search string. The retrieved literature was limited to English language reports of trauma systems in the United States and Canada.

Selection of Retrieved Abstracts for Further Review

Abstracts retrieved by the search string were read independently by two of the authors (N.C.M., R.J.M.). Broad initial inclusion criteria were used to screen abstracts. To be included, abstracts were required to make mention of a comparison or control group when assessing patient outcomes. By using this inclusionary criteria, resulting studies compared trauma outcomes across trauma centers/systems (i.e., geographic analysis), within a trauma center/system (i.e., temporal analysis), or contrasted regional outcomes to a national criterion standard (e.g., the Major Trauma Outcome Study [MTOS]). If no determination could be made regarding a study's research design based on the abstract, the article was retained for further review. Independent author assessments that were in conflict were resolved by open discussion. The resulting articles were pulled and copied for a full review.

Critical Appraisal of Key Articles

Published articles satisfying inclusionary criteria were categorized based on the type of study design underlying the evidence: panel review, comparison to a national criterion injury registry, or population-based studies. Panel review studies use an expert panel to review the medical records of injured patients who die to reach a conclusion regarding whether the patient could have survived given optimal treatment. The outcomes are often designated as "preventable" or "nonpreventable." The second type of study design uses a large criterion injury registry to generate predicted survival or mortality rates, which are then compared with observed survival or mortality. A commonly used "national" trauma database is the MTOS. Studies in the final study design category rely on large existing databases to evaluate the outcomes of entire populations in a region or state. These studies often use hospital claims data or vital statistics data to evaluate outcomes.

For the purposes of this study, the strength of evidence associated with each article was assessed by using a three-tier classification system developed to assess the traumatic brain injury literature. Class I studies are represented by prospective randomized controlled trails. Well-designed prospective or retrospective controlled cohort studies, or case-control studies compose Class II evidence. Other quasi-experimental studies that use existing databases, registries, or rely on case series data are considered Class III evidence. Studies providing case reports, literature reviews, or information based on expert opinion were not considered appropriate evidence for this investigation.
Some ambiguity may exist regarding whether a retrospective study should be defined as a Class II or Class III study. We attempted to demarcate these class types based on the study's level of control over the constitution of the comparison group. Observational studies that use a comparison group that differs from the test group by geographic location or time period demonstrate little control over the selection process and were deemed Class III evidence. On the basis of this assumption, care was taken to characterize study attributes that would be considered relevant in making a distinction between the two classifications. Examples of pertinent attributes would be; case identification, sample size, study setting (single vs. multiple centers), an adequate description of the composition of the comparison group and other study methods.

Key attributes associated with reviewed articles were identified and recorded. These attributes characterized the research design, sample features, potential biases, and research findings for each study. The attributes were tabled as "evidence" associated with each of the three study design classifications. The resulting evidence tables formed the basis on which the published evidence was reviewed during the Academic Symposium to Evaluate Evidence Regarding the Efficacy of Trauma Systems held July 16 to 18, 1998, at The Skamania Lodge, Stevenson, Washington. Four of the authors carefully reviewed the preliminary evidence tables and formally presented an analysis of the evidence at the symposium (R.J.M., E.M., G.J.J., C.N.M.). Based on comments received at the symposium and the in-depth review conducted by these authors, the evidence tables were revised and finalized.

RESULTS

Literature Retrieval and Review

A total of 245 articles were identified in the initial electronic data search. The MEDLINE search yielded 4 articles (1966-1974), 53 articles (1975-1984), 64 articles (1985-1989), 59 articles (1990-1994), and 32 (1995-1998). CINAHL and HealthSTAR contributed 2 and 31 additional articles, respectively. One hundred seventy-four abstracts met the inclusion criteria. An additional 39 studies satisfying inclusion criteria were identified by reviewing citations among included articles. Many of the additional studies predated the electronic data search. Based on a full-text review, 242 articles were found to not include an adequate comparison group and were excluded from further review. Thus, a total of 42 studies were included in the literature synthesis phase of the review. Studies demonstrating Class III or better evidence (n = 40) were organized into evidence tables. For the purpose of completeness, details about patient populations, definitions, and statistics from individual cited studies are contained in the evidentiary tables and are not repeated in this text. A detailed assessment of individual studies in each evidence table is provided in three companion articles appearing in this supplement.15-17

Panel Studies

Table 1 presents the evidentiary table associated with studies that use expert panels to determine whether trauma systems are effective in reducing the incidence of "preventable" death. Two additional studies met preliminary inclusion criteria,18,19 but were excluded from the table because of either a small sample (n = 27) or limited expert panel (n = 1). The evidence table characterizes the type of injuries and number of deaths reviewed, the panel size and composition, possible sources of panel bias, and the outcomes resulting from the panel review.
TABLE 1. Evidentiary table associated with panel

Columns 7 and 9-11 in Table 1 document study attributes that may bias the findings associated with the panel review of patient records. For example, panel members may rely on personal knowledge about a familiar health care system when assessing trauma deaths (column 7). To avoid this type of bias, the panel should be composed of members "outside" the system under study. Panel members should also be "blinded" as to the intervention status of each case (e.g., pre-trauma center or post-trauma center death [column 9]). The type, quality, and amount of retrospective data available to panel members may also bias conclusions regarding the "prevent-ability" of death (column 10). For example, autopsy reports may cite more injuries with greater severity than can be abstracted from a hospital chart. Finally, panel assessments are known to vary based on whether the data review was performed independently or in a group setting (column 11)\(^{20,21}\). In addition to biases listed above, other limitations have also been associated with panel studies.\(^{22}\) In essence, panel studies represent structured case series studies and are, therefore, categorized as Class III evidence.

**Comparisons to National Injury Registries**

Table 2 details 11 studies relying on large injury registries to compare expected deaths with observed deaths (or survival). Most studies rely on MTOS to generate predicted death rates. However, The Trauma Coma Data Bank and The National Pediatric Trauma Registry have been used for this purpose. Statistics specifically designed to assess comparisons to MTOS are provided in columns 10 through 12. Because local trauma registries often provide the data to be benchmarked, sample sizes and the diversity of injuries assessed are often larger in scope than can be accomplished in a panel study.

TABLE 2. Evidentiary table associated with registry studies

Registry comparison studies are susceptible to a unique set of potential biases and limitations. Registry data are often limited to assessing outcomes at a single trauma center rather than evaluating combined outcomes from several trauma centers. This observation may be due to inconsistencies in trauma registry data protocols across centers, making comparisons difficult. Authors also cite that MTOS data are not population based and has become quite dated (1989).\(^{23}\) Temporal changes in injury demographics and case mix greatly complicate the appropriate application of national registries.\(^{23}\) Overall study design, known difficulties with severity scoring,\(^{24,25}\) and case-mix comparability dictate that registry comparisons be categorized as Class III evidence.
Population-Based Studies

Table 3 provides the evidentiary table associated with studies that use readily available large databases to assess patient outcomes with in a trauma system. Most studies use large existing collections of claims data or vital statistic data, allowing the effect of trauma systems to be assessed with in an entire region or state. Before 1990, most studies relied on unadjusted death rates to compare the outcomes of patient populations. In subsequent years, multivariate models were applied to "statistically control" for recognized differences in patient demographics and/or injury severity. Several studies attempt to focus on outcomes among the most severely injured, with the assumption that this population is most likely to benefit from specialized trauma care. Common study designs include presystem versus postsystem comparisons or trauma center versus non-trauma center comparisons.

Limitations associated with the use of existing databases include incomplete data capture \(^{26,27}\) and a potential for a systematic bias when coding procedures and injuries for an alternate purpose (e.g., claims data) \(^{28,29}\). Because existing data points are rarely specific to the question under investigation, some precision is lost when using the best available proxy variable. These data restrictions often limit the usefulness of multivariate models \(^{30}\). Although rarely reported, most models explain a limited amount of variance present in the data. Also, death as an outcome occurs infrequently in claims data, further exacerbating the ability of multivariate modeling to adequately predict this rare event \(^{31}\).

Aside from the limitations associated with analyzing existing databases, population-based studies may provide the most robust evidence regarding the effect of trauma systems on patient outcomes. The large sample sizes, broad spectrum of included injuries, and complete sample capture add credence to the findings reported by this category of studies. However, because existing databases are used, these studies are classified as providing "high-end" Class III evidence.

DISCUSSION

Evidence tables resulting from an extensive literature review document variance in the type and quality of study protocols used to assess the effect of trauma systems on patient outcomes. Early studies rely on a panel of experts to identify substandard trauma care. Later studies attempt to standardize optimal trauma care by instigating a national criterion standard to benchmark regional trauma outcomes. Currently, evidence regarding trauma system effectiveness is likely to stem from population-based studies relying on existing claims or vital statistics data to associate patient outcomes with trauma system implementation.

Obvious limitations in the current published literature include the sole reliance on hospital survival as a measure of trauma system effectiveness. Limited published work acknowledges prehospital deaths,
and no published work incorporates a survival measure after hospital discharge (e.g., 30-day survival). A second limitation involves the reliance on mortality as an adequate measure of trauma care effectiveness. Several published studies in the evidence tables indicate that trauma systems may provide benefit for patient populations most likely to be physically or mentally disabled by the injury.\textsuperscript{57,58,67,68} Adequate outcome measures should incorporate disability measures, rehabilitation outcomes, life satisfaction, and long-term functional status to quantify the protracted effect of a systematic approach to trauma care.

Many tabled studies appear quite susceptible to systematic biases that may potentially dilute the impact of study findings. In some cases, additional attention to study design details may have alleviated some potential biases. However, it is not clear from the documentation provided in several articles whether these apparent weaknesses are the result of poor descriptions of actual study methods or true design oversights on the part of investigators.

The literature review did not reveal studies that provide Class I or Class II evidence regarding trauma system effectiveness. Realistically, true prospective randomized controlled trials cannot be implemented, in the traditional sense, when assessing patient outcomes after injury. However, prospective cohorts or well-matched case-control samples are entirely possible and would substantially enhance the current literature. Aside from the temporal and concurrent biases associated with the type of comparative studies listed in the evidentiary tables, there is solid Class III evidence regarding the impact of trauma systems on hospital survival.

In the absence of compelling evidence regarding trauma system effectiveness, there is still a need to critically assess the current literature to determine future research directions and to identify commonalities in study findings that may guide current policy decisions regarding the implementation of trauma systems. The evidentiary tables resulting from our systematic literature search form the bases for three detailed reviews of the current literature appearing in this supplement.\textsuperscript{15-17}

**SUMMARY OF EVIDENCE TABLE REVIEWS**

Each of the three evidence table reviews provide specific findings resulting from careful evaluation of the included articles in each table.\textsuperscript{15-17} In this concluding section, the authors provide a brief coalition of findings specific to the question: "Do trauma systems improve patient outcomes?"

The authors agree the currently published literature limits our ability to assess trauma system effectiveness by excluding important components of care delivery (e.g., prehospital deaths) and failing to incorporate measures of short-term survival and functional outcome among patients surviving to hospital discharge. Other common insufficiencies include the application of comparison groups that restrict patient samples based on injury severity or geographic locale. Limitations and biases specific to each of the three study designs further diminish the reliability and validity of reported results. We conclude, however, that consistencies among reported findings in each table suggest that hospital mortality is reduced among the seriously injured with implementation of systematic trauma care in urban areas.

Panel studies demonstrate a reduction in the number of preventable deaths with increasing commitment to trauma care resources and expertise.\textsuperscript{15} The best evidence resulting from panel studies (published in the 1980s) suggest a 50% reduction in the preventable death rate with implementation
of trauma centers, the bulk of this reduction being associated with inappropriate or suboptimal hospital care before trauma center implementation.\textsuperscript{36, 38, 39} Trauma registry data originating from designated trauma centers\textsuperscript{44, 45, 50, 51} uniformly demonstrate a 15\% reduction in mortality when compared with MTOS norms.\textsuperscript{16} Population-based studies, incorporating multivariate modeling to control for covariates,\textsuperscript{64-69, 71, 72} demonstrate a 15 to 20\% reduction in the risk of death after a trauma center/system is in place.\textsuperscript{17}

The consistency with which evaluated studies report improvements to the survival of hospitalized patients does lend credence to the supposition that organized systems of trauma care are effective health care policy. However, other critical issues such as the cost-effectiveness of organized trauma care remain relatively unexplored. Further work that uses more sophisticated study designs (Class II) is needed to determine whether trauma systems improve patient outcome and are fiscally sound across the entire continuum of care required to return injured patients to an optimal state of functioning.

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REFERENCES


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