Survival Advantage for Elderly Trauma Patients Treated in a Designated Trauma Center

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Abstract

Background

This paper analyzes the effectiveness of designated trauma centers (DTC) in Florida concerning reduction in the mortality risk of severely injured elderly trauma victims.

Methods

Inpatient hospital data collected by the Agency for Health Care Administration were used to identify elderly trauma patients. An instrumental variables method was used to adjust for pre-hospital selection bias in addition to the influence of age, gender, race, risk of mortality, comorbidities, and type of injury. The model was estimated using a bivariate probit full information maximum likelihood model to determine the impact of triage to a trauma center as opposed to a non-trauma hospital.

Results

After adjusting for confounding influences, treatment at a designated trauma center was associated with a statistically significant reduction of 0.072, 0.040, and 0.036 in the probability of mortality for, respectively, 65-74, 75-84, and 85+ year old patients.

Conclusions

Treatment of severely injured elderly trauma patients in designated trauma centers is associated with statistically significant gains in the probability of survival.
Survival Advantage for Elderly Trauma Patients Treated in a Designated Trauma Center

"Growing old is a pretty lousy thing to have happen to you, until you consider the alternative."
-- George Burns --

Florida is a unique place for the elderly. Its population has the highest proportion of elders in the U.S. with almost 18 percent aged 65 or older. The impact of this distinctive demographic statistic is especially profound on hospital providers. In 2007, Medicare was the primary payer for over 41 percent of Florida’s inpatient hospital episodes, accounting for over 51 percent of all hospital charges in the state, indicating a major utilization impact on this industry. In response, hospitals fulfill a fundamental role in the production of good health for the elderly, affecting longevity, quality of life, and mortality.

The focus of this analysis is on survival of elderly trauma victims, who were admitted and discharged from a Florida hospital between 2003 and 2007. The objective is to determine whether elderly trauma victims who are triaged to DTCs have a survival advantage as has been demonstrated for non-elderly adults and children in previous research. In other words, are trauma centers relatively more effective than their non-trauma counterparts pertaining to the production of good health in the elderly trauma victim population? While studies examined trauma system effectiveness, few have focused exclusively on survival of the elderly patients, an important segment of the population, particularly in Florida. As discussed below, important questions exist about the appropriateness concerning triage rates of elderly trauma patients to trauma centers. Establishing the effectiveness of trauma centers in terms of survival advantage for this age cohort is necessary to help frame and guide best trauma triage protocols and practices. The next section provides a brief discussion of the background associated with the elderly and the Florida trauma system. This will be followed by a description of the data and
methods used to estimate the impact of trauma centers and the results of the empirical estimation, and their implications.

**Background**

The Florida trauma system includes 21 DTCs, which are classified as Level I (7), Level II (12), or pediatric only (2). All Level I and four of the 12 Level II hospitals are also certified as pediatric centers. The Florida Department of Health, Office of Trauma (DOH-OT 2009), defines a trauma patient as “any person who has incurred a physical injury or wound caused by trauma and who has accessed an emergency medical services [EMS] system.” Classification of a victim as a trauma alert by EMS is an important determinant of triage to a DTC. A trauma alert is defined as “a person whose primary physical injury is a blunt, penetrating or burn injury, and who meets one or more of the adult trauma scorecard criteria in Rule 64J-2.004, F.A.C. …” Pertaining to the context of this study, one crucial criterion for classification as a trauma alert is whether the patient is aged 55 years or older. If meeting this condition, in conjunction with one of six other criteria,* classification as a trauma alert is automatic. Florida's trauma protocols require trauma alert patients to be transported to the nearest trauma center if one is located within 50 miles by air transport or within 30 minutes by air or ground transport. In general, most areas in Florida are within this travel distance (Figure 1).

![Figure 1: Florida Trauma Hospitals with 50 Mile Buffer >>](http://www.doh.state.fl.us/demo/Trauma/PDFs/AdultTraumaCriteriaMeth1202.pdf)

The presence of the 55+ age condition for trauma alert classification suggests the elderly should have a higher likelihood of triage to a DTC in case of injury, holding all other factors

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* The other criteria to be met in conjunction with age 55 or older, pertain to (a) airway, specifically, a respiratory rate of 30 or greater, (b) circulation, specifically, a sustained heart rate of 120 beats per minute or greater, (c) best motor response, specifically, a value of 5, (d) cutaneous, specifically, soft tissue loss or gunshot wound to the extremities, (e) longbone fracture, specifically, single FX site due to MVA or Fall 10’ or more, (f) mechanism of injury, specifically, ejection from vehicle or deformed steering wheel. Victims can also be classified as trauma alters if they meet a single severe injury criteria as described on the trauma score card (http://www.doh.state.fl.us/demo/Trauma/PDFs/AdultTraumaCriteriaMeth1202.pdf)
constant. However, existing research focusing on triage of elderly trauma victims in Florida suggests the opposite, indicating the elderly are less likely to receive treatment in a DTC. For example, Phillips et al. (1996)\(^6\) concluded that the “triage criteria comprising the trauma scorecard produce unacceptable levels of undertriage in elderly patients.” Similarly, Pracht et al. (2006)\(^7\) examining trends in triage of trauma victims in Florida from 1991 to 2003 show that, unlike their pediatric and non-elderly adult counterparts, the elderly had a DTC-triage rate below 50 percent in the final year of their study. Interestingly, the authors also report that the elderly were the only age group to experience an increase in per capita mortality following injury during the study period. For severely injured elderly trauma victims, only 50 percent were transported to a DTC, compared to 85 percent for non-elderly adults.

A number of studies, including three focusing on Florida, have analyzed trauma system effectiveness, measured in terms of the probability of in-hospital mortality from serious trauma.\(^1,2,3,8\) Studies focusing on the elderly that provide evidence supporting a survival advantage associated with treatment in a DTC include Tepas et al. (2000) who focused on non-injury comorbidities in addition to trauma, Meldon et al. (2002) who examined outcomes in elderly trauma victims in a community-based study, and Mann et al. (2001) who examined outcomes before and after the implementation of a trauma system.\(^8,9,10\) Contrasting the above mentioned studies, Mackenzie et al. (2006) did not find a significant difference in outcomes for the elderly based on the site of treatment in a nationwide study. However, as the authors point out, their data included a limited number of severely injured older patients which may have affected the particular finding.\(^11\)

To what extent is there a survival advantage pertaining to elderly trauma patients treated at a DTC? Clearly, the practical significance of the perceived under-triage concerning the
elderly depends first and foremost on the existence of a benefit derived from treatment at a DTC. For example, the absence of such survival benefit could render irrelevant any under-triage related concerns. Thus, the main objective of this study is to determine the survival advantage for the elderly, which is expected to be less than that associated with non-elderly adults since the marginal health product of medical care, defined as the change in health status following intervention, is expected to diminish with advanced age. The dataset used for this analysis (see below) revealed that the elderly, aged 65 and older, accounted for 47 percent of trauma patients classified as severely injured using the ICD-9CM Injury Severity Score (ICISS) method, providing additional weight to the importance of the research.

**Data and Methods**

The primary data source used in the analysis is the Florida Inpatient Hospital data for 2003 to 2007. The data are collected and maintained by the Agency for Health Care Administration (AHCA) and contain demographic and diagnosis related information for all inpatient episodes occurring in Florida acute care general hospitals. Potential trauma patients are identified through ICD-9CM codes, indicating fractures, other than those related to the skull, neck, and trunk (ICD-9CM codes 810-829); fractures of the skull, neck, and trunk, intracranial injury, and spinal cord injuries (ICD-9-CM codes 800-809, 850-854, and 952); internal injury of the thorax, abdomen, or pelvis (ICD-9-CM codes 860-869); injury of blood vessels (ICD-9CM codes 900-904); and burns (ICD-9-CM codes 940-949). A second criterion is then applied to identify trauma patients, which is designation of the hospitalization as emergent, as opposed to urgent or elective. Finally, to be included in the analysis, a patient must have had at least one injury associated with a severe risk of mortality (ICISS < 0.85). The survival risk ratios (SRRs) and the derivation of the ICISS values are discussed in more detail below.
In addition to these inclusion criteria, the primary study sample was restricted to trauma patients 65 years of age or older. Determining the effectiveness of a treatment intervention for the elderly is relatively problematic, compared to non-elderly adults, because of the confounding influence of their physiologic condition, a characteristic which is difficult, if not impossible, to observe and incorporate into a statistical model. However, it is logical to expect anatomic changes and reduction in physiologic reserves to play a more intense role, on average, as a patient’s age increases. Eventually, the influence of such is expected to overpower conventional intervention options. To incorporate this phenomenon into the analysis, the model was estimated for three mutually exclusive age groups, as well as the pooled sample.

Breaking down the sample by successive age groups also helps address a potentially serious source of measurement bias. Advanced age is associated with reduced physiologic reserves as well as increased probability of co-morbidities that will likely affect mortality, in ways that cannot be accounted for in the model using observable patient and diagnosis related characteristics, including injury severity. Two unobservable factors may be especially important in case of the elderly. The first relates to medical futility, referring to cases in which death in the hospital is inevitable due primarily to the patient’s advanced age as opposed to, for example, the effectiveness of the treatment. The second factor concerns advanced directives referring to cases when a decision is made by, or on behalf of, the patient to cease further medical treatment. Within the cohort of elderly, the influence of both of these sources of bias is expected to increase with age; for example, injuries which may result in almost certain mortality in the case of a 85-95 year old individual may not be fatal to a 65 year old counterpart.\textsuperscript{13,14} Therefore, while exact age cutoff points for the influence of these biases are, admittedly, not possible to calculate, logic suggest they should be greater for older subgroups. To account for this likely source of bias, at
least partially, and to examine the related sensitivity of the results the data will be analyzed separately for patients aged 65 to 74, 75 to 84, and 85 and older.

**Estimation**

The estimation method used in the analysis and its rationale have been well established in the relevant literature examining the effectiveness of trauma centers.\(^2,3,15,16\) The following will provide a brief outline of the method while the technical discussion is provided in the appendix. The outcome of interest in this analysis is mortality, measured as dichotomous with a value of one if the patient died in the hospital and zero otherwise, thus suggesting either Logit or Probit as appropriate estimation techniques. The primary equation to be estimated may be expressed as

\[
\text{mortality}_i = \beta'_i \beta + DTC_i \gamma + e_i
\]

where \(\text{mortality}_i = 1\) is observed when the patient did not survive, \(x_i\) is a vector of statistical controls that affect the probability of mortality, \(\beta\) is the associated vector of coefficients, DTC is the treatment variable of interest, \(\gamma\) is the coefficient associated with it, and \(e_i\) is a stochastic error term. Existing studies examining DTC effectiveness suggest the existence of serious selection bias associated with the observed mortality and the treatment variable,\(^2,3,16\) indicating that a single equation model estimation would not produce consistent results. The presence of an endogeneity problem in this study’s sample was verified using a Hausman test (\(p = 0.04\)).\(^17\) Further evidence for the selection bias is provided below in the discussion concerning the descriptive statistics in Table 1. To solve this problem, a second equation is required, in essence, to simulate randomized triage of trauma victims between DTC and non-trauma center (NC) hospitals. The second equation estimates the probability of triage to a DTC and is specified as

\[
DTC_i = x'_i \alpha + d'_i \delta + u_i
\]
The right hand side of this equation differs from that of the first equation by the inclusion of an instrument, relative distance \( (d) \) that is not present in the first equation. The rationale underlying the selection of the instrument is discussed in McClellan et al. 1994, McConnell et al. 2005, Pracht et al. 2007, and Pracht et al. 2008. The results from the instrumental variables (IV) estimation method are unbiased and consistent.\(^{15}\) These equations are then estimated simultaneously using a bivariate probit full information maximum likelihood approach, using the Qualitative and Limited (QLIM) Dependent Variables procedure in SAS. The results of single equation estimation, not adjusting for the selection bias, are discussed briefly in the appendix for comparison.

Injury severity, measured as the ICISS score, is expected to be the most important predictor of mortality. The ICISS values used in this research were derived from SRRs calculated from the 1993-2002 Florida hospital data, including both DTC and NC hospitals. The 10 years preceding the study sample were used to avoid introducing simultaneity bias into the model. An SRR indicates the proportion of victims that survived after being admitted for the associated diagnosis. Because the current study focuses exclusively on the elderly, the SRRs were calculated using only hospitalizations involving the relevant age group. This is essential since the elderly are systematically different in their physiologic response and mortality risk to injury.\(^{2,3}\) Higher ICISS values indicate a lower level of severity, thus, a negative relationship is hypothesized between the odds of mortality and the ICISS.\(^{18,19,20}\)

The ICISS score, as opposed to other popular severity measures such as the ISS or AIS, was used in this study based on the research by Rutledge et al. (1998)\(^{19}\) and Kilgo et al. (2004).\(^{20}\) Rutledge et al. performed a direct comparison of ICISS and ISS and concluded the former outperforms the latter in predicting several outcome measures, including mortality, length of
stay, and hospital charges. Kilgo et al. examined whether the ISS is a monotonic function of mortality and raised concerns about the validity of the measures in a significant percentage of trauma cases.

In addition to the treatment variable and the severity measure, the controls in the model consist of demographic and other patient and injury characteristics. The demographic factors consist of patient age, gender, and race. Even though the data includes only the elderly, more advanced age within this cohort is hypothesized to be associated with an increased probability of mortality, ceteris paribus. Female gender and race, including whether the patient was black, Hispanic, or other non-white, are included in the model to account for any differences in these cohorts that may affect the outcome. Four patient characteristics are included in the model. In addition to the ICISS score, discussed above, the model includes three dichotomous variables indicating whether the patient had one, two, or three or more co-morbidities. Finally, the model also includes dichotomous variables indicating whether the patient had a skull or spinal cord injury (SSCI), a traumatic brain injury (TBI), an injury to the thorax, or a vascular injury. Fractures classified as neither SSCI nor TBI, i.e. those in the ICDCM range of 810 to 829, served as the statistical control for injury type in the model. The model does not adjust for the level of trauma center since a secondary analysis (see appendix) did not find a statistical difference concerning the elderly based on type of center.

The main equations, discussed below in the results section, were executed including only patients who were treated at the hospital where they originally presented with an injury. Transfers were problematic because the data does not indicate where a patient was transferred to, only that the patient was transferred to another short term acute care hospital. Therefore, it was not possible to assess empirically what percentage of transferred patients moved from NC to
DTC, or vice versa. To determine, whether omitting transferred patients from the sample
affected the results, a sensitivity analysis was performed, the results of which are discussed in the
appendix. The inclusion/exclusion of transfers changed neither the estimates nor the conclusions
of the study.

Results

Trauma involved over 13 percent of hospital episodes of the elderly, making it a
significant source of admissions. Furthermore, while the 2007 gross mortality rate associated
with all hospitalizations for this population was slightly more than 2.5 percent, mortality was
3.4% in the trauma patient population, regardless of severity. When only the severely injured
(defined below) were included, the mortality rate increased to 9.5 percent, underlining the
importance of better understanding survival among the elderly.

Table 1 contains the descriptive statistics of the data for the pooled and sub-samples. To
reiterate, only patients with an ICISS < 0.85 were included. The overall mortality rate was 10.53
percent, ranging from 9.48 to 11.18 in, respectively, the 65-74 and 85+ categories. The
percentage of the patients who received treatment in a trauma center declined from 50.31 to
35.85 and 27.19 in, respectively, the 65-74, 75-84, and 85+ age groups. Motor vehicle accidents
play a declining role as patients get older: the percentage of elderly trauma victims hospitalized
following a traffic related motor vehicle accident declines from 13.61 to 4.20 based on age
group. Concerning injury type, skull and spinal cord injuries are the most prominent in all age
groups, but grow in importance as age increases. The next most important injury type is
traumatic brain injury, followed by injuries of the thorax, fractures, burns, and vascular injuries.
The comorbidity profile of elderly trauma victims implies chronic pulmonary disease (20.03%),
diabetes without complications (15.83%), and congestive heart failure (15.06%) to be the most
common. Other comorbidities that occur in over 4 percent of this population are myocardial infarction, cerebrovascular disease, dementia, peripheral vascular disease, and renal disease.

Table 1 provides a comparison of patients by type of hospital and severity level. The overall mean ICISS level in the pooled sample is 0.70, ranging from 0.66 (more severe) to 0.73 (less severe) in, respectively, the 65-74 and 85+ samples. The mean ICISS level in the trauma center population (0.624) is significantly lower, indicating greater severity, compared to the non-center population (0.744). The severity level in the center population is also associated with greater variability as measured by a standard deviation of 0.23 compared to 0.14. The distribution in Table 2 shows the percentage of victims in nine ICISS intervals with a width of 0.10. The data clearly indicate that the trauma center population is more severely injured. For example, whereas less than one percent of the non-trauma center population has an ICISS < 0.10, the proportion in the trauma center patient population in that category is 4.59 for all age groups. A similar relative pattern holds for all ICISS categories with the exception of the lowest severity groups.

The sub-samples were selected to mirror established age groupings typically used by large data collection agencies including the CDC and the U.S. census bureau. The age groups are 65 to 74, 75 to 84, and 85 plus. The results of the Bivariate probit model are shown in columns 2, 3, and 4 of Table 3. The last column contains the results of the pooled sample. To facilitate interpretation of the non-linear coefficient, the marginal effects of each variable in the
model are shown in Table 4. The marginal effects provide a measure for the instantaneous effect that a change in a variable has on the predicted probability of mortality, holding the other variables constant. They are calculated by evaluating the derivative of the probability density function with respect to the variable in question.

The treatment variable of main interest in this analysis is center, indicating whether or not an elderly patient received treatment at a designated trauma hospital. The coefficient associated with this variable is significant in the equations for the 65 to 74, the 75 to 84, and the pooled samples. In the sample containing only patients aged 85 and over it is significant only at the 10 percent level. The marginal effect of the center variable, evaluated at the averages, indicates that patients aged 65 to 74 triaged to a trauma center have a survival advantage of a little over seven percent. This positive change in the probability of survival declines to four percent for patients aged 75 to 84. For the most elderly patients it declines further still to 3.6 percent; as mentioned above, for this age group, the effect is not statistically significant at the five percent level. When all elderly are pooled in one sample, the marginal effect was 3.9 percent.

The following is a brief summary of the influence of the control variables in the model. The most significant predictor of mortality is, as expected, the severity associated with a patient’s combined injuries. The ICISS variable is highly significant in all equations. The calculated marginal effects associated with the severity variable indicate changes in the probability of mortality of 43, 45, and 48 percent for patients aged, respectively, 65 to 74, 75 to 84, and 85 years and older.

The influences of demographic characteristics are mixed. More advanced age is associated with greater mortality in all three cohorts. Female patients have a lower probability of mortality, holding other variables constant. Within the context of age, compared to whites,
blacks do not have a different probability of mortality in any of the equations. However, Hispanics aged 75 to 84 had lower mortality, while other non-white patients had higher mortality in the 85 and older group.

Co-morbidities and type of injury play an important role. The marginal effects associated with the variables indicating whether a patient had one, two, or three or more co-morbidities show a clear pattern in all equations. For example, for patients aged 65 to 74, the probability of mortality increases by 1.6, 5.3, and 7.6 percent as the number of co-morbidities increases from zero to one, two, or three and over. This increasing pattern is consistent for all age groups but is more compact for the most elderly patients. Concerning injury type, the control group consists of patients hospitalized due to a fracture other than those associated with SSCI (skull and spinal cord injuries) or TBI (traumatic brain injury). The results suggest that patients with SSCI tend to have lower probability of mortality while those with TBI consistently experience increased mortality. Patients with injuries related to the thorax are associated with lower probability of mortality. Finally, patients with vascular injuries did not have a significantly different probability of mortality.

In addition to the behavior of the individual coefficient estimates, the overall significance and fit of the model were examines. The log-likelihood ratio and Wald chi-square statistics indicate that the model has statistically significant explanatory power (p < 0.0001). In a comparison of predicted probabilities and observed responses, 86.2 percent matched, indicating that the model provides a strong fit for the data.

Conclusions and Discussion

The primary objective of this study was to (a) establish whether elderly trauma patients have a survival advantage if triaged to a designated trauma center, and (b) quantitatively estimate
the size of that advantage. The results indicate that significant survival gains could be realized if triage rates of the elderly, currently at 50 percent of those with severe injuries, were brought in line with the 85 percent of their non-elderly adult counterparts. The results of the analysis indicate that all but the most elderly (85+ years) experience a significantly lower probability of mortality when triaged to a DTC. For the 65 to 74 age group, the estimated marginal effect associated with the center variable is 0.072. Using the inverse of the ICISS as a proxy, the average elderly trauma victim in the sample had an expected mortality of approximately 0.30. The results of this study suggest that triage to a trauma center reduces the expected mortality for such an average victim in the 65 to 74 age group to 0.228. It should be reiterated that the marginal effects were calculated using averages and that it will diminish as one moves toward the extremes of, say, injury severity; within this context, it is noteworthy that the bulk of patients, by definition, tend to be near the average (for example, over 50 percent of NC patients had an ICISS within 0.15 points of the 0.65 average in the sample of severely injured patients indicating an ICISS < 0.85).

The analysis illustrates important age based differences within the elderly cohort. The marginal effect associated with the center variable declined significantly, from 7.2 to 4.0 percent, in the 75 to 84 age group. Moreover, within the oldest cohort, ages 85 and over, the marginal effect declined further and was not longer statistically significant at the 0.05 level (p=0.08).

Injuries affect the elderly differently compared to their non-elderly counterparts and tend to be associated with greater difficulty in treatment, worse outcomes, and higher cost. This analysis verified the life saving potential of DTCs but also highlights the importance of injury severity. A small reduction in the severity of injury can reduce the probability of mortality by 0.43 for the 65 to 74 age group; for the most elderly patients, the marginal impact of severity
increases to 0.48. While trauma centers provide a survival advantage to the injured elderly, the greatest gains can be achieved through injury prevention.

One of the potential biases the analysis had to address pertains to the end-of-life concerns, particularly as they relate to medical futility in the elderly trauma population (see methods section). Unfortunately, the administrative database utilized for this study did not contain information on planning for end-of-life care or implementation of end-of-life protocols. Current Medicare regulations require documentation of life expectancy of less than 6 weeks and a do-not-resuscitate order to qualify for reimbursement as hospice care. In the hectic time immediately after an injury event, achieving consensus from family and caregivers for implementation of hospice care is a clinical challenge. We believe this approach needs to be changed. Recent reports suggest that healthcare professionals with end-of-life care training should participate early in the care of patients where there is a significant chance for death as an outcome. Many elderly trauma patients would qualify for end-of-life planning if such an approach was used. The presence of do not resuscitate or withdrawal of care permissions are prone to error in terms of underuse and overuse in elderly trauma patients. Data on the presence or absence of such documents would, by itself, not be a reliable indicator of the efficiency of end-of-life care planning. Additional efforts directed toward patient and caregiver education are warranted in this important area of trauma care.

The results of this analysis indicate potentially significant survival gains for severely injured elderly patients through increased triage to DTC. However, by necessity it is limited in scope, addressing but a single facet of an extremely complex and extensive problem. For example, automatic triage to a DTC, based solely on age, would likely result in over-triage, overwhelming existing trauma hospitals. Pudelek (2002) described the elderly as a special
population with special needs, a portrayal that is both general to life itself and specific to trauma. Special rules, prior to, during, and after hospitalization are necessary to ensure proper triage, inpatient hospital protocol, treatment, and rehabilitation of this population. The significance of the challenges concerning trauma in the elderly population will increase with the size of this age group. Understanding these challenges has important implications for effective decision making pertaining to all aspects of treatment of the elderly.

While potential survival gains are clear from increased triage of elderly trauma patients, in the 65-84 age range, to designated trauma centers, the current study highlights the difficulties in managing elderly trauma victims. Compared to their non-elderly counterparts, the elderly experience greater risk of mortality from specific injuries and associated complications. At first glance, this suggests the elderly should be given priority concerning triage decisions to determine the site of care. However, the apparent consensus in the literature suggests the potential survival gains associated with non-elderly adult trauma patients triaged to DTCs are substantially larger, averaging at approximately 15 percent. If all elderly trauma patients in the current dataset, ages 65 to 84 with an ICISS < 0.85, had been treated in a DTC in the last year of the study period (2007), the estimates derived here suggests 18 lives saved. In comparison, using a 15 percent survival gain associated with treatment at DTC for non-elderly adult trauma victims, an estimated 114 lives would be saved if the same triage criteria were applied to this age cohort. A large part of the difference is explained by the absolute sizes of the different cohorts; however, if the relative gains were measured in life years, as opposed to individuals saved, the difference would grow disproportionally larger given the obviously longer life expectancy of the non-elderly.
This analysis was conducted using an administrative dataset not specifically designed for research purposes. A limitation related to the design of the dataset is the absence of variables regarding patients' anatomic or physiologic factors. The instrumental variables approach used in the estimation is designed to, at least, partially account for the influence of such unobservable characteristics. However, it is itself the source of an additional limitation; in particular, the results apply to the marginal, as opposed to the average patient, meaning those who are affected by the instrument, differential distance to a DTC. However, since more than 74 percent of the patients in the sample lived closer to a NC than a DTC, a significant majority of them can be considered “marginal.” Finally, the data were limited to one state, affecting the ability to generalize the finding. Because trauma systems are heterogeneous, the results of this study may not apply to other state or regional systems.

The results of this study provide strong evidence that the probability of mortality is statistically significantly lower for most elderly trauma patients when treated at designated trauma centers, ceteris paribus. The comparatively low percentage of elderly trauma patients treated at centers suggests there may be deficiencies in triage or access to such hospitals for this vulnerable cohort. However, in practice, economic realities involving scarcity and consequent tradeoffs in the allocation of resources suggest caution. This study provides but a piece of a very complex multidimensional puzzle which includes prevention, necessarily limited-information triage decision making, and geographically variable DTC capacity considerations.

In conclusion, a brief history and suggestions concerning the triage of elderly trauma patients may provide further context to the problem at hand. The Florida trauma system is governed by regulations formulated and promulgated by the Florida Department of Health. The Department receives regular input from committees composed of health professionals who are
active in the trauma system. The initial response to data suggesting under-triage of elderly trauma patients to Florida trauma centers was to make age 55 years and older a criterion for determining the patient to be a “trauma alert” requiring transport to a designated trauma center. This change has had limited effect since many elderly trauma patients are injured in falls and have associated symptoms that may suggest the etiology of the fall to be a stroke, hypoglycemic episode, or myocardial infarction. Frequently, the presence of a traumatic brain injury is not immediately apparent. Moreover, many trauma patients are initially evaluated by primary care physicians who may direct EMS personnel to transport the patient to a non-trauma center.

Discussions of this problem are ongoing. Some possible solutions include education of elderly citizens and healthcare providers regarding the definition of traumatic injury and the benefits of trauma center care; and development of requirements for EMS personnel to inform the patient and/or caregiver that trauma center care is appropriate.
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Appendix

The Instrument

The proposed instrument is based, in part, on the time cost of transporting victims. Following McClellan et al. (1994) and Pracht et al. (2007) differential distance to alternative treatment sites is measured as a straight line from the geographic center of the victim’s residence zip code and the nearest DTC minus the distance to the closest NC with an emergency department (ED). Distance influences a patient’s destination since Florida’s EMS protocols dictate that patients be transported to the nearest ED or DTC in case of a trauma alert.

The validity of differential distance as an instrument depends on two crucial assumptions: (a) it is sufficiently correlated with the DTC variable independent of other exogenous variables, and (b) it is uncorrelated with the outcome variable, mortality. In other words, it must not be a significant omitted variable from the outcome equation. The first criterion was easily verified using the second equation and a Wald test, showing it to be highly statistically significant. The second condition is more difficult to test and cannot be definitively proven. The selection is based on both theoretical grounds and statistical tests. The distance variable is based solely on geographic location and is, therefore, a plausible choice. It represents not only the time cost related to transport to a DTC but also the tendency of trauma hospitals to locate in regions associated with high levels of trauma and, therefore, strongly influences the selection. To examine the potential correlation between the distance variable and mortality two tests were performed. First the data were stratified based on distance in 10 mile intervals from a DTC. A standard chi-square test showed that distance did not influence the outcome. The p-value (0.78) suggests that the null-hypothesis that distance does not influence the outcome cannot be rejected using the data at hand. A second more formal chi-square test was used to verify whether the
distance variable is a legitimate instrument. This test is used to assess whether the instrument is a significant omitted variable from the primary equation. The results (chi-square = 1.32) indicates that it does not influence the error term significantly. Based on these tests, differential distance is not simply an omitted variable from the structural equation as argued on theoretical grounds.

The results of single equation logit estimates were examined to assess the impact of selection bias. The outcome of these equations, which by definition are biased, not consistent, and statistically inefficient, suggests that DTC are associated with increased probability of mortality compared to NC. For example, in the pooled equation, the single equation logit model produced an odds ratio of 1.53 (p < 0.01) suggesting significantly increased mortality for patients triaged to a DTC. This contradictory result indicates substantial selection bias, which, if not corrected in statistical estimation would produce incorrect conclusions concerning the effectiveness of trauma systems.

**Level I versus II**

The Florida trauma system has three types of centers: Level I, Level II, and Pediatric. The Level I hospitals also have pediatric certification and a teaching mission. Other than that, level I and II centers are organized similarly, at least where it concerns caring for non-pediatric patients. Whether or not the level mattered for the elderly was analyzed using the same instrumental method as in the current study to adjust for selection bias (in this case the instrument was differential distance to the nearest Level I center). The results did not reveal a statistically significant difference between the types of hospitals where it concerned the elderly. The results of the equation comparing Level I and II hospitals are shown in the table below. All the variables behave as expected. While the Level I variable has a negative coefficient, it is not statistically significant (p=0.16).
Table A: Results of a Bivariate Probit Model Comparing Level I and Level II TC

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.029</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Female</td>
<td>-0.230</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Black</td>
<td>-0.151</td>
<td>0.0421</td>
</tr>
<tr>
<td>Hispanic</td>
<td>-0.070</td>
<td>0.2864</td>
</tr>
<tr>
<td>Other non-white race</td>
<td>0.029</td>
<td>0.7325</td>
</tr>
<tr>
<td><strong>Level I</strong></td>
<td><strong>-0.123</strong></td>
<td><strong>0.1588</strong></td>
</tr>
<tr>
<td>ICISS</td>
<td>-3.182</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>A single comorbidity</td>
<td>0.115</td>
<td>0.0031</td>
</tr>
<tr>
<td>Two comorbidities</td>
<td>0.394</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Three plus comorbidities</td>
<td>0.457</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Is SSCI</td>
<td>-0.007</td>
<td>0.8902</td>
</tr>
<tr>
<td>Is TBI</td>
<td>0.242</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Is Torso</td>
<td>-0.247</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Is Vascular</td>
<td>-0.010</td>
<td>0.9117</td>
</tr>
</tbody>
</table>

**Transfers**

To determine the sensitivity of the results to the exclusion of trauma patients who were transferred from one acute care hospital to another, the models were re-estimated including such patients. The estimated coefficients of the model variables did not change significantly. For example, in the pooled model, the number of observations increased by 2.6 percent from 28,988 to 29,772. The number of non-surviving patients did not change by the inclusion of transfers. The coefficient associated with the treatment variable of interest (center) changed from -0.271 in the model excluding transfers to -0.253 when such patients were included. The p-value did not change.