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Explaining the Difference in the Triage Rate of the Elderly: Are they Undertriaged or Not?

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Abstract

In Florida, the percent of injured elderly trauma patients with ICISS < 0.85 who were transported to a designated trauma center (DTC) was only 47.9 in 2013, which was about half the triage rate of non-elderly adults. This present analysis used Florida hospital discharge data to examine the difference in these triage rates by analyzing injury type, severity, and mechanism, distance to a DTC, and severity of comorbidities. Falls were the largest mechanism of injury among severely injured elderly (72.9 percent) yet had the lowest triage rate to DTCs (33.0 percent) among injury mechanism categories. In contrast, motor vehicle accidents (MVAs) were the most frequent for non-elderly adults (54.9 percent), which were associated with relatively high triage rates for both severely injured non-elderly and elderly (88.4 and 70.9, respectively). The severity of comorbid conditions may explain why severely injured elderly patients are less likely to be transported to a DTC. The severity of comorbidities among the elderly had a greater association with mortality than the ICISS, creating a need for paramedics to determine whether the DTC or closest hospital is the better alternative. The elderly have equal geographic access to trauma centers in Florida; however, they are less likely to use them, particularly for ground level falls, which often do not require surgery.

Introduction

Designated trauma centers (DTCs) play a critical role in state systems designed to reduce death due to injury. They are intended to receive severely injured patients who benefit from the consolidation of care by a specially trained trauma team directed by a trauma surgeon and including other surgeons, anesthesiologists, emergency physicians, and other consulting specialists, technicians, and ancillary support personnel. The classification of a patient as severely injured is a vital element in the decision whether treatment is sought at a DTC. Logically, research examining whether injured patients have appropriate access to DTC have focused primarily on injury severity. The severity measures used in such research have typically been calculated retrospectively from inpatient records which provide a complete picture of the patients' diagnoses, demographic characteristics, geographic distribution, and mortality outcomes. A high proportion of severely injured patients treated at a DTC is then interpreted as evidence that access is adequate.

This paper shows that using the simple proportion of severely injured patients triaged to a DTC, while indicating utilization of trauma services, may be misleading when measuring the adequacy of access to DTC. Access implies not only proximity but also need for the unique services of DTC. In contrast, utilization merely means that treatment was received at a DTC. The analysis examines various characteristics of elderly and non-elderly adult trauma patients to construct an epidemiologic profile of these cohorts to provide insight into the possible reasons for age based utilization differences. While the data used here are from a single state (Florida), the processes and issues relevant to the decision whether to expand a trauma system by adding DTCs are more or less global as are the potential implications. Among all states, Florida has the highest proportion of elderly, providing a unique opportunity to analyze the differences. This may assist policy makers in assessing or further developing existing trauma triage protocols.

Background

In 1982, the Florida legislature authorized the State's department of health to designate hospitals as trauma centers. More recently, in 2004, the Florida legislature requisitioned a comprehensive analysis of the trauma system. At the time, 19 of Florida's 218 acute care hospitals had been designated as adult trauma center [1]. Since then, additional adult trauma centers have been approved, increasing the total to 27 DTCs in 2014.

The literature pertaining to the Florida trauma system from the past decade has focused on the survival advantage associated with treatment at a DTC [2-5] and the adequacy of "access" to trauma services [6-8]. Research on utilization of inpatient trauma services revealed significant age related differences exist in the rate of triage of severely injured trauma victims to DTCs. In 1996, the proportions of severely injured children and non-elderly (NE) adults treated at a Florida DTC were, respectively, 67 and 66 percent. By 2010, these proportions reached 93 percent for children and 85 percent for NE adults, indicating a highly efficient triage system for these age groups. In contrast, the proportion of severely injured elderly patients treated at a DTC increased to only 41 percent in 2010. The factors contributing to the relatively low triage rate of severely injured elderly patients to DTCs are unclear. Florida's trauma triage protocol has attributed extra weight to age of 55 years or older in determining whether to treat an injury as a trauma alert [9], which should, in theory, result in a higher proportion of severely injured elderly triaged to a DTC, if assuming all other factors constant. The extra consideration given to older age, combined with the lower proportion of severely injured elderly triaged to DTCs raises doubt that the low

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triage proportion associated with the elderly results from a systematic under-triaging.

A series of analyses found a significant survival advantage associated with treatment of severely injured patients at Florida's DTCs. Moreover, the survival advantage is enjoyed by all age groups up to age 85 years [2-5]. The largest benefit of triage to DTC in case of severe injury accrues to non-elderly adults, defined as individuals between 16 and 64 years of age.

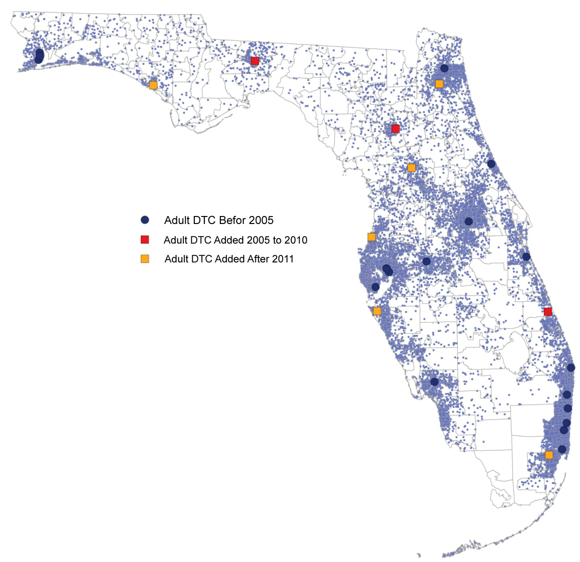

Figure 1: Distribution of DTCs in Florida

In 1996, with 16 DTC for adults, 66% and 27% of, respectively, non-elderly adults and elderly with ICISS < 0.85 were treated at a DTC [8]. By the time "A Comprehensive Assessment of the Florida Trauma System" [10] was published in 2005, Florida had 18 adult DTCs and trauma triage rates of severely injured NE-adults and elderly were, respectively, 78 and 32. Partly based on the recommendations of that report, three additional hospitals were designated as DTC (one Level I and two Level II) while one former DTC in Pensacola discontinued its designation, recognizing a DTC surplus had existed in this city. The additional trauma centers were located in areas that had previously been remote from the existing trauma centers, thus closing geographic gaps in the system. The additions are shown in (Figure 1) as red squares, whereas the DTC already in place before the comprehensive assessment are shown as blue circles. Each blue dot on the map represents 1000 residents.

Following this expansion of the number of DTC, the percentages of severely injured non-elderly adults and elderly treated at DTC increased substantially to, respectively, 85.6 and 49 percent in 2010. After 2010, six additional hospitals were certified as DTC, which are shown as yellow squares in (Figure 1). One is located in Florida's panhandle and was recommended in the Comprehensive Assessment of the Florida Trauma Systems since it is located over 50 miles from the nearest DTC. The State's trauma triage protocols identify a DTC service area as 50 miles when air medical service is available. The remaining five new DTCs were located in areas already served by one or more trauma centers based on the 50-mile standard. One of the new DTCs subsequently lost its certification, indicating a net increase of four centers added to areas already served by a DTC. Despite the additional centers certified after 2010, the percentage of severely injured non-elderly adults treated at a DTC did not change by 2013 (Figure 2). The percentage of severely injured elderly actually declined below its 2010 peak of 48.5, with 47.9 percent triaged to a DTC in 2013. The 2013 levels did not differ significantly from the 2010 levels in either age cohort.

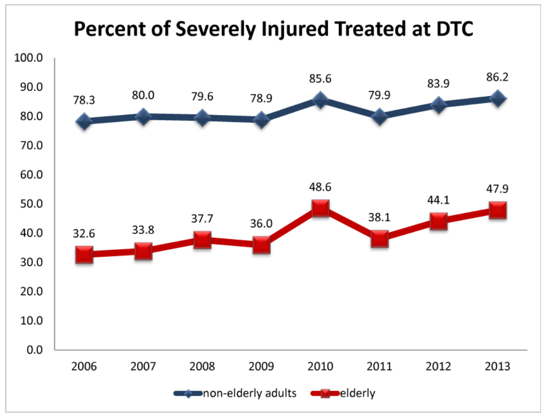

Figure 2: The percentage of severely injured non-elderly adults and elderly treated at a DTC.

Thus, the data clearly suggest that the additional centers did not increase utilization of trauma center services, indicating a need for further analysis of triage rates of severely injured patients to DTC, particularly of the elderly. The comparatively low triage rate of severely injured elderly to DTCs has been widely discussed in the literature [11-17]. The earlier literature, including research focusing on the Florida trauma system, generally assumed that the low triage rates among the elderly were the result of ineffective triage criteria. More recently, Ciesla et al., 2013 [7,8] have pointed to other potential explanations for this phenomenon, including differences in injury mechanisms, types, and patient preferences. This paper expands on these inquiries by providing a more in-depth comparative analysis of various characteristics of non-elderly and elderly adult trauma victims, including injury mechanism, injury type and severity, distance from patient residence to the treating hospital, and the impact of comorbidity severity on outcomes.

Data and Methods

The data used for this analysis were obtained from the Florida Agency for Health Care Administration (AHCA) for 2006 to 2013. While earlier years were available, changes in the structure of the datasets, including the number of secondary diagnoses (which increased from nine to 30) and dedicated injury mechanism (e-code) fields, dictated the analysis be limited to the last eight years for consistency. The AHCA data includes patients from both DTC and non-trauma hospitals (NTC) and includes records for all inpatient injury episodes that occurred in the state. It includes a primary diagnosis and up to 30 other diagnoses, patient demographics, the primary payer, the outcome, and the discharging hospital. Trauma patients were identified using ICD-9 codes, their admission priority, and injury severity.

Injured patients were identified as those with an ICD-9 code between 800 and 959, excluding patients with a single injury which, historically, has not been associated with risk of mortality as indicated by the survival risk ratio (SRR). SRRs were calculated using a five year moving interval, utilizing the years before the one in question to avoid same-year bias, and are defined as the number of patients with a specific diagnosis who survived divided by the total number of patients with that diagnosis. The five year moving SRR calculation was used to account for time sensitive changes. Finally, inpatient episodes must have been classified as an emergency in the admission priority field to be included in the analysis.

Injury severity was determined using the ICD-9 Injury Severity Scores (ICISS) which were calculated using the SRRs described above. ICISS values are calculated as the product of the SRRs associated with each individual injury incurred by the patient. Following recent related analyses [2,4-8,18,19], a severity threshold of ICISS < 0.85, implying a probability of mortality of at least 15 percent, was used. This threshold is, admittedly, arbitrary and is used here as a reference point, distinguishing between patients associated with relatively high risk of mortality who have, as a group, been shown to benefit from treatment at a DTC [2-5]. Injury severity is recognized as one factor among many that determine whether a patient should be triaged to a DTC.

Comorbidity severity scores (CSS) were calculated using a method similar to ICISS but applied to the subset of hospitalizations with a recognized diagnosis as the primary reason related to the inpatient episode [20]. Only the principal diagnoses were used in the calculation to avoid introducing biases in the outcomes resulting from other medical conditions. This method produced a weighted comorbidity severity score related to the historic inpatient mortality associated with a particular set of illnesses. Comorbidity survival risk ratios (CSRRs) were calculated using a five year moving window, utilizing the years before the one in question to avoid same-year bias. A comorbidity which is associated with zero mortality will have a CSRR of one, while at the other extreme; comorbidities that always result in inpatient mortality would have a CSRR of zero. Therefore, more severe comorbidities have lower CSRRs. Finally, the comorbidity severity score (CSS) is then calculated as the product of all CSRRs recorded during a given inpatient episode. The comorbidities considered in the analysis were the latest specified by AHRQ [21] and include congestive heart failure, valvular disease, pulmonary circulation disorders, peripheral vascular disease, hypertension, paralysis, other neurological disorders, chronic pulmonary disease, diabetes without chronic complications, diabetes with chronic complications, hypothyroidism, renal failure, liver disease, chronic peptic ulcer disease, HIV and AIDS, lymphoma, metastatic cancer, solid tumor without metastasis, rheumatoid arthritis, coagulation deficiency, obesity, weight loss, fluid and electrolyte disorders, bold loss anemia, deficiency anemia, alcohol abuse, drug abuse, psychoses, and depression.

Having established that the percentage of severely injured elderly trauma patients treated at a DTC has remained low relative to their non-elderly adult counterparts, the following variables were analyzed to explain this finding: the type of injury, the mechanism of injury, the number and severity of injuries, the geographic distribution of patients using their residence zip code, and the influence of comorbidity severity.

The elderly were defined as patients between 65 years of age and older. Non-elderly adults include all patients from 15 to 64 years of age. While Florida trauma triage criteria define 15 year old patients as pediatric, they are counted as NE-adults in this analysis to match the age ranges used by the U.S. Census which was used to calculate rate of injury based on the state's population. This difference from other literature on the subject is not expected to be significant as 15 year old patients accounted for only 0.1 percent of all inpatient hospital episodes involving injury.

Results

Injury type

The percentage of severely injured elderly and non-elderly adults treated at a DTC by five major injury types, fractures other than skull and spinal cord injuries (SSCI) or traumatic brain injury (TBI), SSCI other than TBI, TBI, injuries to the thorax and abdomen, and vascular injuries are shown in (Table 1). The overall triage rate to DTC is shown in the second column labeled "all." The data indicate significant difference based on injury type, with patients experiencing severe vascular injuries having the highest rate of triage to DTC: 96.2 percent of non-elderly and 69.3 percent of elderly patients with vascular injuries were triaged to a DTC in 2013. The next highest rate of triage to a DTC is associated with TBI with a 93.9% rate for non-elderly and 61.1% for elderly. The third highest rate is associated with injuries to the thorax and abdomen, covering 88.1% and 53.6% of, respectively, non-elderly adults and elderly severely injured patients. The remaining injury types, fractures and SSCI, are associated with lower than the overall triage rate for both age groups.

	Non-Elderly Adult Severely Injured Patients										
	Non-elderly (All Severe True Trauma) Triaged to DTC						**Percent of patients with specific injury**				
	All	Frac	SSCI	TBI	Torso	Vasc	Frac	SSCI	TBI	Torso	Vasc
2006	78.2	58.6	73.8	90.8	79.3	88.2	7.4	36.7	41.1	62.6	7.0
2007	79.9	63.9	75.5	90.9	81.3	93.7	8.0	37.0	40.0	61.6	7.6
2008	79.8	66.1	75.5	89.9	80.3	93.4	8.1	36.8	40.8	59.8	7.6
2009	79.1	62.2	73.4	89.8	81.1	92.2	7.4	37.1	42.1	58.7	7.4
2010	85.6	77.9	81.3	93.0	85.8	91.7	4.4	38.6	43.5	65.5	8.3
2011	79.8	55.4	75.3	91.5	83.2	92.5	6.6	37.6	42.1	60.0	8.0

2012	84.0	71.5	79.4	92.7	85.5	94.5	7.2	38.9	41.4	57.4	6.9
2013	86.0	73.0	82.4	93.9	83.1	92.8	7.1	38.7	42.0	59.5	7.7
Mortality associated with injury type							1.7	2.6	13.9	7.0	14.8
	Elderly Severely Injured Patients										
2006	32.4	23.3	25.8	44.7	42.0	63.7	8.3	37.5	49.6	23.0	2.0
2007	33.7	27.2	26.9	45.6	41.4	62.8	9.7	36.2	49.4	22.7	2.2
2008	37.9	29.5	30.4	49.9	42.3	63.2	9.6	34.3	51.6	21.1	2.0
2009	36.2	24.4	29.2	50.8	41.4	67.2	8.9	36.7	50.6	21.2	2.1
2010	48.5	41.5	42.2	54.3	48.7	70.6	3.1	30.7	62.1	27.1	2.6
2011	37.9	23.6	30.8	52.5	45.1	66.9	6.7	38.4	51.2	21.4	2.4
2012	44.2	29.2	37.1	58.1	50.4	76.6	6.2	39.2	50.7	23.4	2.5
2013	47.9	37.1	40.4	61.1	53.6	69.3	6.7	39.3	49.5	22.8	2.1
Mortality associated with injury type							2.3	4.1	11.3	9.6	19.2

Table 1: The percentage of severely injured elderly and non-elderly adults treated at a DTC by injury type

The right hand columns of Table 1 show the percentage of patients in each age group that presented with any of the five injury types. The percentages add to over 100% as patients frequently present with multiple injuries. The data show important differences between the age groups. For NE adults, in 2013 the order of frequency is injuries to the thorax and abdomen (59.5%), TBI (42%), SSCI (38.7%), vascular injuries (7.7%), and fractures (7.1%). For the elderly, the most frequently occurring injury is TBI (49.5%), followed by SSCI (39.3%), injuries to the thorax and abdomen (22.8%), fractures (6.7%) and vascular injuries (2.1%). The relevance of these age based differences is implied by the mortality rates associated with the different injury types. The last row for each age group on the right side of the table shows the corresponding mortality rates over the entire period. The highest rate of mortality is associated with vascular injuries. The proportion of NE adults with this injury type is 3.5 times that of the elderly. The next highest mortality rate is associated with TBI. A higher percentage of elderly (49.5%) experience TBI compared to 42% of non-elderly. Elderly with TBI have the second highest proportion of triage to a DTC, with the first being vascular injuries. The third highest mortality rate is associated with injuries to the thorax and abdomen. As was the case with vascular injuries, in 2013 a substantially higher proportion of the non-elderly (59.5%) present with such injuries compared to the elderly (22.8%).

Finally, the simple correlations between the annual average percentage triaged to a DTC by injury type and the historic mortality rate associated the specific injuries were calculated. For the non-elderly, the correlation coefficient was 0.95, indicating a strong correlation between expected mortality associated with a type of injury and triage to a DTC. For the elderly, the correlation coefficient increases to near unity (0.99). The relationships between the percent triaged to a DTC and the observed mortality is depicted in (Figure 3). The chart shows the lower DTC triage rate of the elderly but also indicates a consistent relationship between expected mortality and triage to a DTC for both age groups.

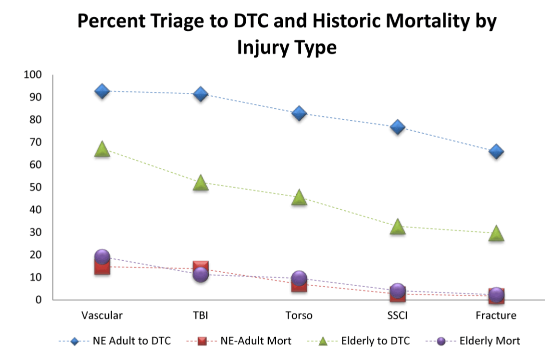

Figure 3: The relationship between the percent of elderly triaged to a DTC and observed mortality by injury type

Injury Mechanism

The distribution of severely injured patients by the most common mechanisms of injury is shown in Table 2. Motor vehicle traffic accidents account for the majority of non-elderly adult trauma related hospitalizations (54.9%). Purposely inflicted injuries and falls are the second most important cause of injury for this cohort, accounting for, respectively, 14.8 and 13.6 percent. Non-traffic related accidents, usually involving recreational or sporting activities, account for merely 3 percent of injuries, while other road vehicle accidents make up 2.7 percent of injuries. Finally, self-inflicted injuries account for 2.3 percent of severe injury related inpatient episodes. The distribution of injury mechanism for the elderly is starkly different, with falls accounting for the most by far (73%) of all severe injury inpatient episodes. It is noteworthy that over a third of falls in the elderly group were classified as "same level." Almost half of falls in the elderly cohort were classified as "unspecified." Motor vehicle traffic accidents were a distant second with 15.9 percent. Finally, purposely inflicted and self-inflicted injuries account for, respectively, 0.9 and 0.4 percent of elderly injury hospitalizations classified as severe.

Columns four and five of Table 2 show the mortality rates associated with each of the major injury mechanisms. For non-elderly severely injured patients, the highest mortality rate is associated with self-inflicted injuries (26.2%), although the absolute number of episodes is relatively low, accounting for 2.3 percent of cases. The second highest mortality rate is associated with the most frequent mechanism, particularly, motor vehicle traffic accidents (7.2%). The third highest rate is associated with purposely inflicted injuries (6.5%), followed by falls (5.8%), motor-vehicle non-traffic accidents (5.5%), and other road vehicle accidents (1.9%). Mortality rates for the elderly are higher in each category but follow a similar pattern. While self-inflicted injuries account for few hospitalizations, the mortality rate is high at 36 percent. The second and third highest rates are associated with motor vehicle non-traffic (9.1%) and traffic accidents (9%). Purposely inflicted injuries in the elderly severely injured cohort have a mortality rate of 7 percent. The mortality rate associated with falls, the most frequently occurring cause of hospitalization, was 6.1 percent. The lowest mortality rate in this group is associated with other road vehicle accidents (4.3%).

The final two columns in Table 3A show the percent of non-elderly and elderly severely injured patient who were treated at a DTC by injury mechanism. In general, the higher the mortality associated with a specified mechanism, the higher the rate of triage to a DTC. Self-inflicted injury, for example is associated with 90.6 and 85.6 percent triage to a DTC for, respectively, the non-elderly and elderly. Non-elderly and elderly patients with severe purposely inflicted injuries are triaged to DTC with 85.7 and 68.2 percent rates. Similarly, motor vehicle traffic accidents have DTC triage rates of 88.7 and 70.9 percent for, respectively, non-elderly adults and elderly. The lowest DTC triage for both age groups is associated with falls. Only 59 and 33 percent of, respectively, non-elderly adults and elderly were triaged to a DTC. The simple correlation coefficients between the percent triaged to a DTC and the observed mortality rate associated with the specified injury mechanism were 0.59 ad 0.75 for, respectively, the non-elderly and elderly.

	Percent of Patients		Mortality Percent		% to DTC	
	NE	Elderly	NE	Elderly	NE	Elderly
All	100.0	100.0	7.18	7.00	81.4	39.6
MV* Traffic Accidents	54.9	15.9	7.00	9.12	88.4	70.9
MV* Non-Traffic Accidents	3.0	0.9	5.48	8.99	76.9	55.0
Other Road Vehicle	2.7	1.2	1.88	4.29	60.8	46.1
Purposely Inflicted Injury (by another)	14.8	0.9	6.49	6.95	85.7	68.2
Self-Inflicted Injury	2.3	0.4	26.24	36.44	90.6	85.6
Falls#	13.6	72.9	5.83	6.06	59.0	33.0
Same Level 1	18.1	36.4	3.03	3.90	35.4	28.8
Same Level (push)	0.6	0.1	1.61	2.47	58.1	33.3
Down level	19.8	9.8	4.45	6.44	70.9	35.7
Stairs	6.0	3.7	9.08	8.39	61.3	48.2
Ladder	16.6	2.7	3.36	5.14	69.0	56.1
Building	9.8	0.5	5.52	7.47	85.0	77.9
Hole	2.0	0.0	4.59	0.00	79.8	37.0
Fracture	1.2	0.9	13.18	5.69	41.1	18.5
Unspecified	27.2	46.9	9.44	7.51	49.6	33.0

Table 2: Distribution of Mechanism of Injury, associated mortality, and triage to DTC of severely injured patients

* Motor Vehicle (MV) traffic accidents involving a collision; an example of MV non-traffic accidents is a collision involving an off-road vehicle; an example of an "other" road vehicle accident may involve a pedal cycle accident or animal drawn vehicle accident.

The percent of patients in the sub-categories of falls is based on the total number of falls.

The Number of Injuries and Injury Severity

The partial criteria used here to identify at-risk patients who may benefit from triage to a DTC is an ICISS score of less than 0.85, indicating at least a 15 percent probability of mortality associated with the patients' combination of injuries. Figure 3 shows the percent distribution of injury severity for NE adults and the elderly, charting ICISS intervals of 0.1 up to 0.7. Only the most severe cases were included in the chart to illustrate the relatively greater severity

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associated with injuries in the non-elderly adult cohort. For the omitted range (0.7 to 0.85), indicating relatively lower severity, the percentage of elderly (72.8) exceeded the percentage of non-elderly adults (64.9). In all the most severe injury intervals shown in (Figure 2), there were a greater proportion of non-elderly adults compared to the elderly.

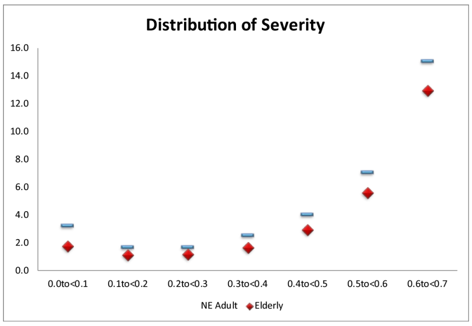

Figure 3A: Percent distribution of injury severity for NE adults and elderly for ICISS < 0.7

The greater injury severity associated with the non-elderly is further illustrated when examining the number of individual injuries recorded in each patient's record. Less than one percent of ICISS < 0.85 group of NE adults (0.91) had a single injury, while 34.19 percent suffered between two and four injuries and 64.88 percent had five or more recorded injuries. In contrast, the distribution of the elderly is skewed toward a lower number of injuries: 5.04 percent had a single injury, 74.84 had two to four injuries, and 21.11 percent had five or more injuries.

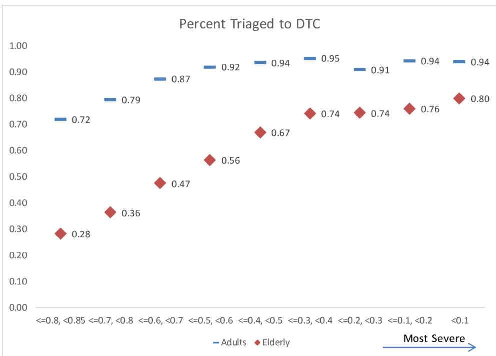

Figure 3B: The percent triaged to a DTC by ICISS interval

The proportion of NE adults and elderly by ICISS interval who were triaged to a DTC is shown in (Figure 3B). As expected, a larger percent of the most severely injured are triaged to a DTC in both age groups. The data also reveal that the gap between the elderly and non-elderly is consistent but smaller in the most severe injury groups.

Distance to Hospital

State trauma protocol requires that injured patients be transported to the nearest trauma center or emergency room. Therefore, the distance from the injury site to the hospital may be an important factor determining the type of hospital where treatment is administered. Because the injury location is not recorded in the data, the patients' zip code of residence is used as a proxy. (Table 3) shows the distribution of distance, measured in miles, from the center of the patients' zip code of residence to the hospital where they were treated. Columns 2-3 show the distribution of all severely injured patients, columns 4-5 show the distribution for patients treated at DTC, and columns 6-7 show the distribution for their counterparts treated at NTC. The data revealed minor age-based difference in the distribution of distances between residence and treating hospital. While a somewhat higher proportion of severely injured elderly live closer to the hospital where treatment was received, the overall distribution is not statistically different (p = 0.9). This finding holds for both the overall population and the hospital type sub-groups. Finally, a closer examination of severely injured patients treated at a DTC revealed that only 26.9 and 25.1 percent of, respectively, NE adults and elderly, lived closer to a DTC than the treating hospital. The difference was not statistically significant.

	DTC and NTC		DTC		NTC	
	NE Adult	Elderly	NE Adult	Elderly	NE Adult	Elderly
0 to<5m	39.09	43.75	37.82	38.95	44.48	46.8
5 to<10m	24.07	25.15	23.81	24.45	25.15	25.6
10 to<20m	18.29	17.24	18.32	17.58	18.19	17.03
20 to<30m	6.81	5.52	7.17	6.96	5.26	4.61
30 to<40m	3.45	2.58	3.67	3.59	2.49	1.93
40 to<50m	2.09	1.57	2.29	2.11	1.22	1.23
50 to<75m	2.85	1.9	3.16	3.06	1.52	1.16
75+ m	3.37	2.28	3.76	3.3	1.7	1.64

Table 3: Distribution of distance in miles from patient residence to treating hospital

Comorbidities

The comorbidity profile of patients may also play a role in the triage decision concerning the type of hospital where treatment is sought. First, the presence of significant comorbidities may imply greater need for immediate care to stabilize the patient. Second, patients with significant comorbidities are more likely to have an established relationship with specific health care providers, including both physicians and hospitals, and may, as a result, have different preferences related to hospital choice. To the extent patients can influence the hospital choice; this may determine where care is received. Table 4 shows the proportion of severely injured patients with a specific number of comorbidities. The proportion of NE adults and elderly without comorbidity is, respectively, 36.1 and 6.9 percent. At the other end of the spectrum, 9.1 percent of elderly patients had six or more comorbidities, compared to only two percent in the NE adult cohort.

Comorbidity Count	NE Adult	Elderly		NE Adult	Elderly
0	29411	5829		36.08	6.86
1	21141	14650		25.93	17.24
2	14366	19391		17.62	22.81
3	8161	17171		10.01	20.2
4	4512	12450		5.53	14.65
5	2242	7749		2.75	9.12
6 or more	1693	7756		2.07	9.14

Table 4: Distribution of the comorbidity count for severely injured elderly and non-elderly adults

To examine the relative impact of comorbidities on the outcome, particularly mortality, probit models were executed for non-elderly adults and the elderly with ICISS < 0.85. In addition to the full sample of elderly injury patients, the equation was re-estimated for three smaller groups based on age in years: 65 to 74, 75 to 84, and 85 and over. In addition to injury and comorbidity severity, each model controlled for the influence of age, gender, race, insurance type and status, and injury type. With the exception of insurance type, all variables were statistically significant at the 0.01 level. Table 5 shows the marginal effects of injury and comorbidity severity evaluated at the variable averages. The negative signs associated with the marginal impacts reflect the inverse relationship between injury and comorbidity severity and mortality. Thus, a decrease in either the ICISS or CSS indicates a greater probability of mortality. In addition to the marginal effects, McFadden's Psuedo R^2 is reported to illustrate the models' goodness of fit.

For the non-elderly, the marginal impact of a change in injury severity (-0.295) significantly outweighs ($p<0.001$) the marginal influence of the comorbidity severity (-0.216). In contrast, the opposite is true for the elderly. In that age group, the marginal impact of comorbidity severity (-0.32) is statistically greater (p=0.001) compared to the marginal influence of injury severity (-0.29). The equations focusing on the subgroups within the elderly cohort indicate that this difference is most pronounced in the 65 to 74 age group ($p < 0.001$) while the difference is not statistically significant in the older groups ($p>0.1$).

The goodness of fit statistic, McFadden's Psuedo R^2, provides further insight into the relationship between the model variables as a group and the dependent variable, the probability of mortality. The values strongly indicate that the model as a whole becomes progressively less effective in predicting mortality the older the population under consideration. A corollary of this finding is that other random and unobserved factors, most likely age related, conspire to produce the outcome.

		Elderly			
	Non-elderly	65+	65 to 74	75 to 84	85+
Count	81526	84996	32205	30151	29145
Injury Severity	-0.295	-0.290	-0.301	-0.305	-0.301
Comorbidity Severity	-0.216	-0.320	-0.340	-0.316	-0.282
McFadden Psuedo R^2	0.450	0.214	0.220	0.223	0.175

Table 5: Marginal effects of injury and comorbidity severity*

*All estimates were significant at $\alpha = 0.01$

Discussion

The age based triage disparity of severely injured patients to DTC versus NTC is a long standing and important policy issue affecting the allocation of trauma resources and the designation of hospitals as trauma centers. The expansion of the state's system from 2005 to 2010 was, at least in part, responsible for a significant increase in the proportion of severely injured non-elderly treated at DTCs. The resulting increase in severely injured elderly patients triaged to a DTC was smaller but still statistically significant. In contrast, the more recent addition of DTCs, adding five Level II DTC, four of which are in existing DTC service areas, did not result in an increase in the proportion of severely injured non-elderly or elderly treated at a DTC. Therefore, one of the main reasons given for the expansion, particularly increasing access to trauma services is doubtful as utilization did not change.

This analysis set out to show that the simple proportion of severely injured patients treated at a DTC provides only a partial picture of the adequacy of access to trauma services by examining a set of factors known to affect triage decisions, including injury type and severity, injury mechanism, distance, and general physiologic condition of the patient. With the exception of distance between place of residence and treating hospital, significant differences were found which may help explain the observed age based disparities. The results showed that injury types associated with high observed mortality are more likely to be treated at DTC regardless of the patient's age.

The next factor examined was the injury mechanism. The majority of elderly with severe injuries were admitted after falls, a substantial proportion of which occurred at the same level. Thus, the results showed that older patients tended to experience from lower energy transfer mechanisms that do not meet the threshold for a trauma alert. An examination of patients with a self-inflicted injuries mechanism provides additional evidence that in field triage decisions, concerning the choice between DTC or NTC, were effective. This injury mechanism was associated with the highest inpatient mortality rate and, as expected, had the highest rate of triage to a DTC: 90.6 and 85.6 percent for, respectively, adults and the elderly.

The overall severity of injuries also provides some insight concerning age based triage disparity. Within the broadly defined group of severely injured, implying ICISS < 0.85, 72.8 percent of the elderly are concentrated in the less severe 0.70 < ICISS ≤ 0.85 range, compared to 64.9 percent of the non-elderly. Since the potential benefit of treatment at a DTC is greatest the higher the severity of a patient's injuries, this difference may also help explain why a smaller proportion of elderly in the ICISS < 0.85 range are triaged to DTC. A closer examination of the number of injuries lends more support to this notion. In the severely injured group (ICISS < 0.85) of NE adults, only 0.91 percent had a single injury, while 5.04 percent of the elderly had only one injury. Similarly, 34.2 and 73.8 percent of, respectively, NE adults and elderly had two to four separate injuries. In contrast, while 64.9 percent of NE adults had five or more separate injuries, only 21.1 percent of the elderly had as many. On the other hand, a larger percent of elderly (31.8%) had at least one injury with an SRR < 0.85 compared to their NE adult counterparts (25%). However, this is likely an artifact of the ICISS methodology which does not account for the presence of comorbidities.

The last factor examined was the relative impact of comorbidity versus injury severity. The presence of comorbidities plays an important role, particularly in the case of the elderly, combining with the impact of their injuries to affect the outcome. Using probabilistic regression, the model indicates that, for non-elderly severely injured patients, an increase in injury severity evaluated at the averages has a larger impact on the probability of mortality compared to an equal change in comorbidity severity. In contrast, in case of severely injured elderly patients, the reverse is true: the impact of an increase in comorbidity severity outweighs the influence of an equal change in injury severity evaluated at the average. This does not imply that the injured elderly do not benefit from triage to a DTC [4]. Holding all other factors constant, the severely injured elderly do experience a significant survival advantage when treated at a DTC, at least up to age 84 years. However, care associated with their comorbidities may be equally or more important and DTC and NTC are not institutionally different, in terms of specialization, in that regard. The model also revealed that it becomes systematically more difficult to predict mortality using the standard factors (e.g. demographics, injury severity, comorbidity severity, etc.) as patients get older. This suggests that the combined effect of countless unobserved random factors becomes increasingly influential with old age. Thus, the low triage rates observed in the elderly may reflect the relative change in the impact of sustained injuries versus intrinsically lower physiologic reserves as opposed to systematic under-triage.

Weaknesses: The data used for the analysis was collected for reasons other than research and, therefore, was subject to inherent restrictions. For example, it does not contain any physiologic measures of the patients' true condition upon admission. Unfortunately, while trauma registries include this information, they do not provide data for non-trauma hospitals. As mentioned previously, the data did not include the geographic location where the injury that led to hospitalization occurred. This forced the use of the patients' residence zip code as a proxy. To the extent that injury location and zip code of residence are different, the section of the analysis that focused on distance to the treating hospital will have been compromised. Finally, state trauma systems are heterogeneous in terms of EMS protocols and structure. For example, in Florida, DTC may be either Level I or II centers, while in Georgia DTCs may be classified as Level I, II, III, or IV. Consequently, some caution is warranted when interpreting and generalizing the results.

Implications: The lower trauma triage rate among the elderly appears best explained by the mechanism of injury relative to Florida's trauma alert criteria. Falls account for 72.9 percent of severe injuries among elderly and yet only 33 percent (of elderly fall victims) were triaged to a DTC, which is the lowest rate among all mechanism of injury categories. In contrast, motor vehicle accidents (MVAs) and self-inflicted injury have the highest triage rates for both groups, and disproportionately impact non-elderly adults, 57 percent of severe injuries versus 16 percent of elderly trauma.

Florida's trauma alert criteria have special considerations for trauma alerting injuries from MVAs. The criteria have included a single long bone fracture from an MVA and age 55 years or older as meeting trauma alert criteria. However, a single long bone fracture from a fall in a patient 55 years or older only qualifies as meeting trauma alert criteria if the fall is from an elevation of 10 feet or more. Further, the mechanism of injury criteria is restricted to motor vehicle accidents, i.e., if the patient is ejected from the vehicle or the steering wheel is deformed from impact with the driver. Mechanism of injury criteria do not exist for falls [22]. Further research should examine the effectiveness of existing triage protocols to assure that elderly patients who would have benefited from trauma services were transported to a DTC.

During the past decade, Florida experienced two periods of DTC expansion. The first, dating from 2005 to 2010 added three new centers, filled large geographic gaps in the system, and was followed by significant increases in the utilization of DTC services by both at risk injured elderly and non-elderly. The second expansion that followed in 2011 and 2012 added six new centers relatively near existing DTC, with one exception in the northwest panhandle of the state. The latter expansion was not followed by an increase in utilization of specialized trauma services which remained unchanged for both age groups examined. In conclusion, this analysis showed that the relatively low DTC utilization rate of injured at risk elderly can, to a large extent, be explained by injury type, injury severity, injury mechanism, and acuteness of non-injury health concerns; the latter include comorbidities and general age related depreciation of physiologic reserves or health stock. To the extent that these factors explain the observed age based disparity in DTC utilization rates of at-risk injured individuals, it cannot be attributed to under-triage. Furthermore, relatively low utilization by the elderly and age based differences in utilization of DTC trauma services cannot be attributed to proximity or access to trauma centers. The observation that adding DTCs in the state after 2011 was not associated with any change in utilization of trauma services by at-risk elderly further supports this conclusion. While utilization did not increase, substantial systems costs were incurred in operating the additional DTCs; therefore, proliferation of trauma centers with the stated objective of increasing utilization of inpatient trauma services by at-risk elderly appears ill-advised.

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