

The Value of Trauma Center Care

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Background: The cost of trauma center care is high, raising questions about the value of a regionalized approach to trauma care. To address these concerns, we estimate 1-year and lifetime treatment costs and measure the cost-effectiveness of treatment at a Level I trauma center (TC) compared with a nontrauma center hospital (NTC).

Methods: Estimates of cost-effectiveness were derived using data on 5,043 major trauma patients enrolled in the National Study on Costs and Outcomes of Trauma, a prospective cohort study of severely injured adult patients cared for in 69 hospitals in 14 states. Data on costs were derived from multiple sources including claims data from the Centers for Medicare and Medicaid Services, UB92 hospital bills, and patient interviews. Cost-effectiveness was estimated as the ratio of the difference in costs (for treatment at a TC vs. NTC) divided by the difference in life years gained (and lives saved). We also measured cost-effectiveness per quality-adjusted life year gained where quality of life was measured using the SF-6D. We used inverse probability of treatment weighting to adjust for observable differences between patients treated at TCs and NTCs.

Results: The added cost for treatment at a TC versus NTC was \$36,319 per life-year gained (\$790,931 per life saved) and \$36,961 per quality-adjusted life years gained. Cost-effectiveness was more favorable for patients with injuries of higher versus lower severity and for younger versus older patients.

Conclusions: Our findings provide evidence that regionalization of trauma care is not only effective but also it is cost-effective.

Key Words: Cost effectiveness, Costs of trauma care, Trauma outcomes.

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Several studies have documented the effectiveness of a regionalized approach to trauma care where critically injured patients are treated in a limited number of designated trauma centers.^{1–7} Most recently, the National Study on the Costs and Outcomes of Trauma (NSCOT) showed that the

risk of death is 25% lower when care is provided in a regional, Level I trauma center than when it is provided in a nontrauma center hospital.¹ This study further documented modest improvements in 1-year physical functioning associated with trauma center care, but only for patients with severe lower extremity injuries.⁷

However, the cost of trauma center care is high, raising concerns about cost-effectiveness and overall value. In today's economic climate, it is critical to conduct rigorous evaluations to determine whether the benefits of expensive therapies warrant their higher costs. In this article, we use data from NSCOT to estimate 1 year and lifetime treatment costs and measure the cost-effectiveness of treatment at a Level I trauma center compared with that at a nontrauma center hospital (nontrauma center).

METHODS

Incremental cost-effectiveness was estimated from a societal perspective using three metrics: cost per life saved, cost per life-year gained, and cost per quality-adjusted life year gained (QALY) associated with treatment at a trauma center versus nontrauma center.

Study Sample

Procedures used in sampling patients for the NSCOT study have been previously described.^{1,7,8} Eligible for inclusion were trauma patients aged 18 years to 84 years treated at 69 participating hospitals (18 trauma centers and 51 nontrauma centers) for a moderately severe to severe injury, defined by an Abbreviated Injury Scale (AIS)⁹ score of 3 or greater. Patients 65 years or older with a first listed diagnosis of a hip fracture were excluded. The study was approved by institutional review boards at all hospitals.

A total of 5,043 NSCOT patients contribute to the cost-effectiveness analysis (1,085 deaths in the emergency department or hospital and 3,958 individuals who survived to hospital discharge). When weighted back to the population of all eligible patients treated at participating hospitals, they represent 15,009 major trauma patients.¹ All patients discharged alive were contacted by phone at 3 months postinjury to assess their functional status and determine their use of health services. Of the 3,958 patients discharged alive, 250 died within 1 year postinjury. Among 12-month survivors, 3,047 (82.4%) consented to a follow-up interview at 1 year postinjury.

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Estimating Costs

One-year treatment costs were derived for the following (1) the index hospitalization in which definitive treatment (trauma center or nontrauma center) was provided; (2) all transport costs and, where applicable, costs associated with treatment at the transferring hospital; (3) subsequent inpatient care including rehospitalizations for acute care, rehabilitation, and stays in long-term care (LTC) or skilled nursing facilities (SNF); (4) outpatient and home health care including services provided by physical and occupational therapists; and (5) informal care provided by family and friends. Estimates of 1-year costs were derived separately for patients who were 65 years and older and enrolled in Medicare (for whom detailed claims data were available from the Center for Medicare and Medicaid Services) and those who were younger than 65 years or older than 65 years but not enrolled in Medicare. Details regarding the approach to estimating costs are published.¹⁰ We summarize the approach below.

Estimating One-Year Costs for Nonmedicare Patients

For patients not enrolled in Medicare, (n = 3,655 aged younger than 65 years, and n = 190, aged 65 years or older), data were obtained from several sources. Costs for the index hospitalization were derived using hospital bills. Where UB92 bills with revenue center detail were provided (90.2% of patients), costs were calculated from charges at the reve-

nue center/cost department line level using cost-to-charge ratios (CCRs) computed from the Medicare cost reports specific to the hospital and fiscal year of the hospital stay. Where line-level CCRs were not available, the overall facility CCR was used. Costs were imputed for those without a reliable index hospital bill (5.1% of nonelderly patients and 3.2% of elderly patients). As it was not feasible to obtain professional fee claims given the large number of physicians involved, we computed the ratio of facility to total costs from the MarketScan Commercial database¹¹ for patients meeting NSCOT inclusion criteria and used this to adjust hospital costs by an average professional fee multiplier, estimated to be 1.27.

All costs other than those for the index hospital stay were derived by multiplying self-reported or record-based units of service (e.g., number of days in a facility, number of physical therapy visits, and hours of informal care) by an estimate of the cost per unit of service (Table 1). All hospital costs were adjusted for regional variation using a weighted mean of wage and capital indexes based on Census Bureau Statistical Area data. All costs were inflated to constant 2005 dollars using appropriate price indices (i.e., inpatient: hospital producer price index [PPI]; emergency department, ambulance, and PT/OT: consumer price index [CPI], professional services; outpatient hospital: CPI, outpatient hospital services; physician part B (carrier) claims: CPI, physician Ser-

TABLE 1. Type and Source of Utilization and per Unit Cost Data for Estimating One-Year Costs for Nonmedicare Enrollees

Cost Component	Type and Source of Utilization Data	Source of Unit Costs
Hospital transport costs	Number and type of transports (air, ground and nonemergency)—obtained from the medical record	Medicare claims by type of transport
Treatment at transferring hospital	Time spent in the emergency department of transferring hospital—obtained from the medical record	Medicare claims for emergency departments at nontrauma centers (the source of all transfers)
Rehospitalizations for acute care	Self-reported length of stay per hospitalization	Facility-specific AHA <i>per diem</i> or, if not available, MCR <i>per diem</i> ; adjusted by the ratio of trauma readmission <i>per diem</i> to overall hospital <i>per diem</i> obtained from MarketScan*. Totals multiplied by the professional fee multiplier
Inpatient rehabilitation	Self-reported length of stay	Facility- or unit-specific MCR <i>per diem</i> or, if not available, facility-specific AHA <i>per diem</i> for rehabilitation-only hospitals; adjusted by ratio of trauma readmission <i>per diem</i> to overall hospital <i>per diem</i> obtained from MarketScan*
Stays in long-term care or skilled nursing facility	Self-reported length of stay	Statewide Medicare covered charges per day for skilled nursing facilities
Outpatient care	Self-reported no. visits by type of visit (physical and occupational therapy; home health; other physician or health care); utilization interpolated for the period between surveys using straight line interpolation	Median allowed MarketScan* charges specific to PT/OT, home health, and other outpatient visits
Informal care from family and friends	Self-reported hours of care (capped at 14 hr/d); utilization interpolated for the period between surveys using straight line interpolation	Mean hourly wages and required benefits for professional caretakers serving adults taken from the <i>Dollar Value of a Day</i> [†]

AHA, American Hospital Association; MCR, Medicare Cost Report.

* MarketScan Commercial database for patients meeting NSCOT population criteria.

[†] *Expectancy Data 2006. The Dollar Value of a Day: 2005 Dollar Valuation.* Kansas: Shawnee Mission, Table 99.

vices; SNF: nursing care facility PPI; Home health: home health services PPI).

Estimating One-Year Costs for Medicare Patients

For patients enrolled in Medicare (1,198 patients aged 65 and older), the principal source of data were claims obtained from Center for Medicare and Medicaid Services, including those for inpatient acute, rehabilitation, and skilled nursing facility stays, outpatient hospital, physician, home health visits, and medical transports. Inpatient hospital costs were computed from charges at the revenue center/cost department line level and adjusted for regional variations in prices, as described above. Professional fees for each hospitalization were obtained directly from claims data. Because LTC stays exceeding 100 days during the benefit period and SNF admissions that do not follow a qualifying acute inpatient discharge are not covered by Medicare, we supplemented the Medicare claims with interview information on reported LTC and computed the extra cost using unit cost estimates as for the non-Medicare patients. Informal care costs were estimated as for the non-Medicare cohort (Table 1). For patients with missing or incomplete data (e.g., those covered by an HMO), costs were estimated using methods described for patients not enrolled in Medicare. All costs were inflated to constant 2005 dollars, as described above.

Projecting Lifetime Costs

Estimates of incremental lifetime costs are needed to derive appropriate estimates of cost per life-year gained.¹² Although we do not have reliable data on differences in long-term costs for patients treated in trauma centers and nontrauma centers, we wanted our estimates of cost-effectiveness to reflect differences in health care costs that accrue in years of life added because of the significant trauma center effect on survival.¹ For this reason, we used age-specific estimates of per capita personal health expenditures for the general U.S. population to model lifetime expenditures based on age at 1 year postinjury and life expectancy as described below.¹³ As part of our sensitivity analysis, we adjusted these estimates upward based on limited data that suggest that lifelong health care expenses exceed those typical of the general population for patients with: spinal cord injury (SCI), moderate to severe traumatic brain injury (TBI), and major limb amputation.^{14–19} Based on this limited literature, lifetime expenditures for SCI, TBI, and amputation patients were assumed to be four, three, and two times that of the general population, respectively.

Measuring Effectiveness

Three measures of effectiveness were derived: incremental lives saved, incremental life years gained, and incremental QALY gained. One-year mortality for NSCOT patients has been reported previously. To estimate incremental years of life gained, we assumed that the survival benefit of trauma center care does not extend beyond 1 year postinjury and that subsequent life expectancy for NSCOT patients is the same as for the general U.S. population of similar age, sex, and race. Based on these assumptions, we used the 2005 U.S. period life tables to calculate expected years of life to

live for each patient based on age at 1 year postinjury, gender, and race. As part of our sensitivity analysis, we adjusted these estimates given published data suggesting lower life expectancy among persons with spinal cord injuries and severe brain injuries. Specifically, we used data from DeVivo and Stover²⁰ who showed that conditional on survival at 1 year postinjury, life expectancy of a 25-year-old is 67% of normal for tetraplegia, 79% for paraplegia, and 86% for partial paraplegia. Data from Shavelle et al.²¹ suggest that life expectancy for a 20-year-old with a TBI receiving inpatient rehabilitation ranges from 48% to 89% of normal depending on the severity of the disability (for this analysis, we assumed a reduction of 80% in life expectancy for severe brain injuries receiving inpatient rehabilitation).

QALY were calculated using observed values on the SF-6D at 3 months and 12 months postinjury²² and projected decreases in future SF-6D scores based on what is known about decrements in function over the life time of the general population.²³ The SF-6D is derived from 11 questions that are part of the SF36v2 and tap into six dimensions of health (physical function, role limitations, social function, pain, mental health, and vitality). Each dimension of health is characterized by five or six levels, which together define 18,000 multiattribute health states. For use in economic evaluations, preference weights have been derived using a standard gamble approach to scaling. SF-6D utility scores range from 0.30 (least healthy) to 1.00 (full health). Persons who die are assigned a score of 0.

The QALY for the first year was computed using values on the SF-6D at 3 months and 12 months (and average using standard trapezoidal rules). For those surviving to 1 year postinjury, we added future QALYs estimated using a life table approach. We started people at their SF-6D assessed at 1 year and decreased this value over future years proportional to differences in SF-6D scores by age reported for males and females in the general population.²³ People who die lose a full QALY per life year. This is a conventional assumption that ignores the fact that some people will not be in perfect health before the injury.

Measuring Cost-Effectiveness

Estimates of incremental costs and incremental effectiveness were derived using data weighted to the population of eligible patients. To adjust for measureable differences between patients treated at trauma centers and nontrauma centers, we used the inverse probability of treatment weighting approach of Robins et al.^{1,24} In this approach, each subject is further weighted by the reciprocal of the conditional probability of receiving trauma center care given detailed demographic and injury characteristics. When comparing lifetime costs with life years gained, we discounted both future costs and life expectancy by 3%, the discount rate for cost-effectiveness analyses suggested by the Panel on Cost-Effectiveness.²⁵

Ratios of incremental costs to incremental effectiveness were derived for all patients and separately for subgroups defined by injury severity and age. To quantify and graphically represent the uncertainty in our estimates, we derived cost-effectiveness acceptability curves (CEACs). CEACs

TABLE 2. Adjusted Mean (SD) One-Year per Patient Treatment Costs (Total and by Service) for Patients Treated in a Trauma Center vs. Nontrauma Center (in US 2005\$)

Service Category	All Patients (\$)	Trauma Centers (\$)	Nontrauma Centers (\$)
Total one year costs	69,076 (93,921)	80,232 (102,268)	58,320 (83,543)
Index hospitalization	37,777 (73,763)	47,933 (80,407)	27,986 (64,894)
Pre-index hospital care	1,702 (20,60)	2,147 (2,351)	1,273 (1,623)
Post-index hospitalization inpatient care	15,703 (42,923)	16,352 (44,966)	15,077 (40,844)
Acute	7,853 (34,394)	8,711 (37,512)	7,026 (31,069)
Rehabilitation	4,968 (15,319)	4,800 (14,353)	5,130 (16,192)
Long-term care	2,784 (12,906)	2,845 (12,529)	2,726 (13,257)
Post-index hospitalization outpatient care	5,794 (9,169)	5,916 (8,874)	5,677 (9,443)
Physical/occupational therapy	2,136 (4,285)	2,253 (4,125)	2,024 (4,431)
Other outpatient services	2,369 (5,648)	2,425 (6,136)	2,316 (5,133)
Home health	1,289 (4,279)	1,239 (3,914)	1,337 (4,603)
Informal care	8,100 (12,254)	7,883 (11,797)	8,308 (12,675)

TABLE 3. Adjusted Mean per Patient Lifetime Costs by Injury Severity and Age for Patients Treated in a Trauma Center vs. Nontrauma Center (in US 2005\$ With 3% Discount Applied to Future Costs)

	Trauma Centers (\$)	Nontrauma Centers (\$)	Difference in Lifetime Costs (\$)
Total	225,747	198,403	27,344
Max AIS			
≤3	220,440	199,079	21,361
4	236,819	202,615	34,204
5–6	228,494	187,597	40,897
Age (yr)			
<55	228,255	218,798	26,339
≥55	218,798	188,383	30,415

were derived by considering incremental costs and incremental effectiveness as random variables with a multivariate normal (posterior) joint density with mean equal to the point estimates and variance-covariance matrix equal to the estimated variance-covariance matrix of the point estimates.²⁶ For a given target ratio on the horizontal axis (which represents the amount society is willing to invest to achieve a unit of effectiveness, e.g., a life or life year saved), the associated point on the CEAC is interpreted as the probability that the observed incremental cost-effectiveness ratio is less than the target ratio. As such, the estimated CEAC summarizes the evidence that trauma centers are cost-effective across a range of potential values of the target ratio.

RESULTS

One-year (unadjusted) treatment costs averaged \$85,362 and \$47,636 for trauma center and nontrauma center patients, respectively. After adjusting for differences in case mix, mean one-year per patient treatment costs were significantly higher for patients treated at trauma centers versus nontrauma centers ($p < 0.01$), largely because of costs incurred during the initial hospitalization. (Table 2) Costs for the initial hospitalization were 71% higher for patients treated in trauma centers versus nontrauma centers.

Projected lifetime costs (discounted at 3%) for patients treated at trauma centers and nontrauma centers are \$230,317 and \$194,255, respectively. When these costs are case-mix adjusted, the difference in per patient lifetime costs is attenuated but remains significant at \$27,344 ($p < 0.01$; Table 3). The difference in mean per patient costs increases with severity and age ($p < 0.001$).

As previously reported, one-year case-mix adjusted survival was significantly higher for NSCOT patients treated at trauma centers than at nontrauma centers, with evidence to suggest differences in the effect by injury severity and, to a lesser extent, by age.¹ Over all ages and severities, there are 3.4 net lives saved per 100 major trauma patients when treatment is at a trauma center compared with nontrauma center. (Table 4).

We projected an average, case-mix adjusted life expectancy from time of injury of 32.8 years for patients treated at trauma centers and 31.4 years for patients treated in nontrauma centers, for an undiscounted increase in life expectancy of 1.40 years per patient. When discounted by 3%, the increase in life expectancy per patient is lowered to 0.7 (or 70 additional life years per 100 patients; Table 4). Projected life-years gained increases by severity and is greater for patients aged less than 55 years compared with 55 years and older.

When future life expectancy is adjusted for quality of life as measured by the SF-6D, the impact of treatment at a trauma center compared with nontrauma center remains unchanged at 70 additional QALYs per 100 patients. This result is expected because the impact of trauma center care on functional outcomes has been shown to be modest.⁷ For patients in the NSCOT study, 1-year SF-6D utility scores were similar (0.70 vs. 0.68 for survivors treated at trauma centers and nontrauma centers, respectively).

The cost-effectiveness ratio for treatment in a trauma center versus nontrauma center is \$36,319 per life-year gained or \$790,931 per life saved (Table 4). The incremental cost per QALY saved (\$36,961) is similar to the cost per life-year gained. Cost-effectiveness ratios are lower for more severely injured patients and for patients less than 55 years of age. When a sensitivity analysis was performed by varying

TABLE 4. Incremental Cost-Effectiveness by Injury Severity and Age (in US 2005\$ With 3% Discount Applied to Future Costs and Life Expectancy)

	One-Year Survival				Total Life Expectancy			
	Percent Surviving in Trauma Centers	Percent Surviving in Nontrauma Centers	Net Lives Saved (per 100)	Incremental Cost per Life Saved (\$)	Mean Life Expectancy in Trauma Centers	Mean Life Expectancy in Nontrauma Centers	Mean Life-Years Gained per Patient	Incremental Cost per Life-Year Gained (\$)
Total	89.6	86.2	3.4	790,931	18.5	17.8	0.7	36,319
Max AIS								
≤3	95.2	94.5	0.7	3,414,599	19.7	19.4	0.3	86,294
4	87.7	83.1	4.6	753,675	17.6	16.8	0.8	44,820
5–6	68.2	55.6	12.6	325,929	15.2	12.4	2.8	14,931
Age (yr)								
<55	93.4	89.2	4.2	632,901	21.8	20.7	1.1	25,123
≥55	79.3	77.5	1.8	1,738,134	9.5	9.3	0.2	174,818

assumptions about future costs and changes in future life expectancy after severe injuries, the estimates were not substantially affected. The adjusted difference in lifetime costs for care in a trauma center versus nontrauma center increases from \$27,344 to \$27,739; the incremental cost per life-year gained increases from \$36,319 to \$36,992.

Figure 1A summarizes the likelihood that the estimated incremental cost effectiveness ratio is less than a targeted dollar value of the cost per life-year gained over a range of potential target values. For example, the likelihood that the cost per life-year saved is \$50,000 or less is 80%. An analysis stratified by injury severity as defined by the maximum AIS score shows that cost-effectiveness is more favorable and more stable for patients with injuries of higher versus lower severity (Fig. 1B). Similarly, cost-effectiveness is more favorable and more stable for younger versus older patients (Fig. 1C).

DISCUSSION

The few studies that have examined the cost-effectiveness of trauma center care have been hampered by inadequate data and limited generalizability.^{6,27} This study provides the most comprehensive data available on both effectiveness and the costs incurred in the year after injury for 5,043 patients treated at 69 trauma centers and nontrauma centers located in 14 states. In particular, estimates of hospital costs are based on detailed billing data, so that all charges (except professional fees, which were added uniformly as a multiple of facility costs) were captured. In most cases, costs were calculated from charges at the revenue center/cost department line level using CCRs specific to the hospital and fiscal year of the hospital stay. In rare cases where a line-level mapping was not possible, the overall facility CCR was used. Where only complete charges were available, facility-level CCRs were used and cost estimates adjusted to take into account the differences in CCRs related to trauma care versus average hospital care.

The incremental cost per life-year saved for treatment at a trauma center versus nontrauma center was estimated at \$36,319 (\$790,931 per life saved) for all major trauma patients defined by NSCOT study criteria. The value of a year of life is the subject of considerable debate.^{28–31} Cutler et al.²⁸ summarize commonly used benchmarks that range from

\$50,000 to \$200,000. Perhaps the most widely cited analysis of the value of a statistical life is that published by Viscusi and Aldy²⁹ who estimate the value for people of working age to approximate \$7 million or more than \$200,000 per year of life remaining for a person aged 45 years who is expected to live an additional 30 years. Cutler et al. and others recommend using a value of \$100,000, whereas the British National Health Service uses an upper limit of \$50,000 in their analyses of alternative health policies.³⁰ A threshold of \$50,000 to \$100,000 is often justified based on the cost-effectiveness of renal dialysis; recent estimates suggest that the incremental cost-effectiveness of current dialysis practice (compared with the next least costly strategy) averages \$129,090, with a wide distribution in values depending on the target population being evaluated.³²

Although the direct comparison of our results with other studies is difficult given methodological differences inherent in cost-effectiveness analyses, two recent reviews of out-of-hospital emergency care and of critical care medicine help put our results in perspective (Table 5). Lerner et al.³³ summarized economic evaluations of 10 emergency medical service interventions for cardiac arrest and found a range of values for the incremental cost per life saved (from \$2,800 to >\$2 million). In comparing 48 cost-effectiveness ratios examining the treatment of severe sepsis, acute respiratory failure, and general critical care interventions, Talmor et al.³⁴ reported ratios ranging from \$1,150 to \$575,054 per life-year gained (and up to \$958,423 per QALY gained). In their analysis of the cost-effectiveness of implantable cardioverter defibrillators, Sanders et al.³⁵ reported incremental cost-effectiveness ratios ranging from \$24,550 to \$50,700 per life-year gained (\$34,000 to \$70,200 per QALY gained). Our estimates of \$36,319 per life-year gained or \$790,931 per life saved are well within an acceptable range of other cost-effective, life-saving interventions reported in the literature.

The cost-effectiveness of trauma center care varies by baseline risk of dying as measured by both injury severity and age. The value of trauma center care is compelling for persons sustaining severe injuries and persons younger than 55 years of age. Estimates of the incremental cost per life-year gained for persons with less severe injuries and persons

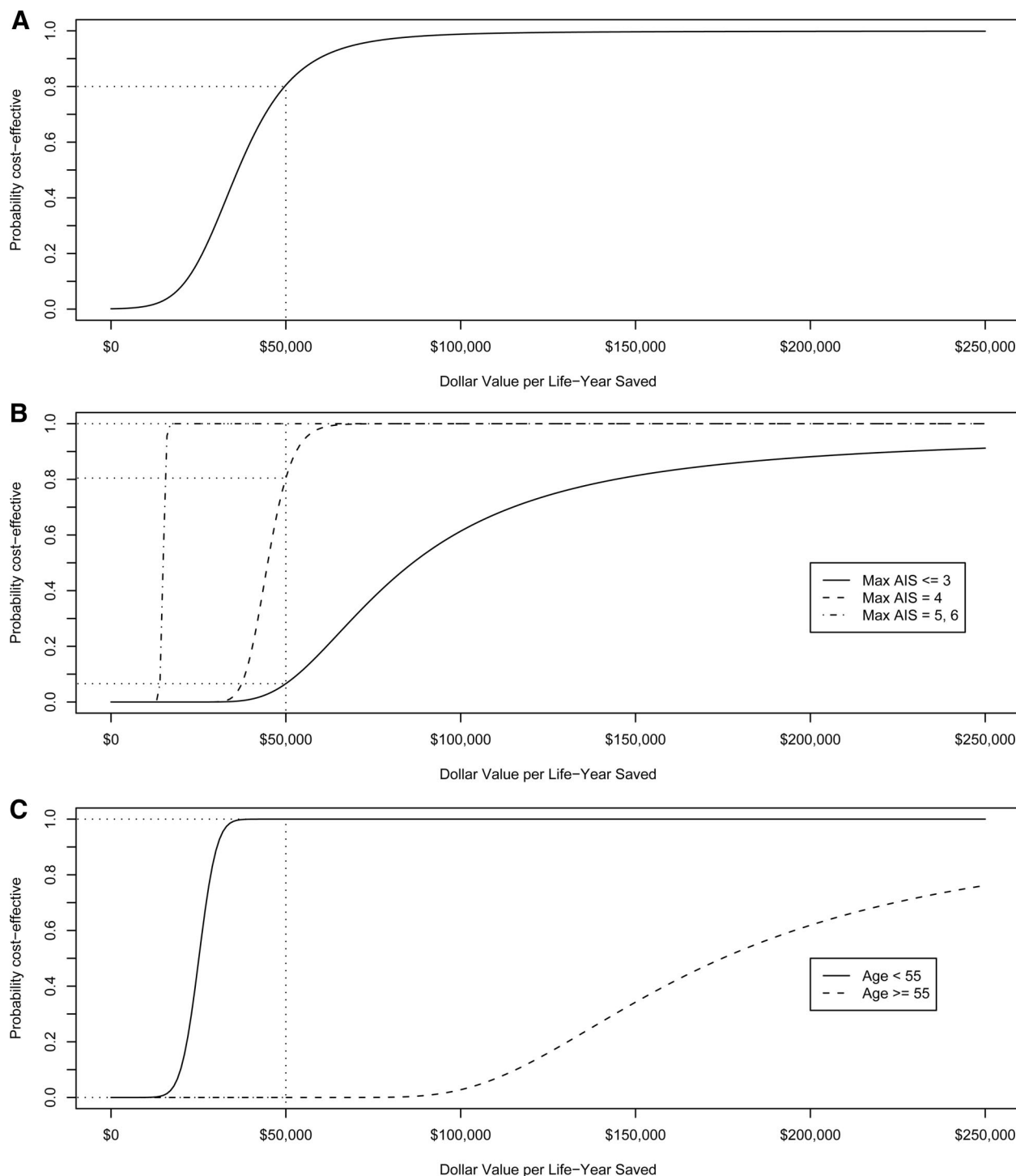


Figure 1. CEAC for all patients and by injury severity and age. A, Overall; B, by injury severity; and C, by age.

aged 55 years and older are less stable and higher (although within the acceptable ranges noted above).

These results further support the need for continued efforts and requisite funding of regionalized systems of trauma care. Although treatment at a Level I trauma center is expensive, the benefits of this approach in terms of lives and

QALYs saved outweigh the costs. However, the higher incremental cost per life-year gained for less severely injured patients underscores the importance of designing these systems, so that they are inclusive and assure that patients are taken to the level of care commensurate with their needs. Although making sure the most severely injured are taken to

TABLE 5. Cost-Effectiveness Ratios for Selected Life-Saving Interventions

Intervention	Comparator	Target Population	Incremental Cost-Effectiveness Ratios*
Prophylactic implantation of an implantable cardioverter defibrillator (ICD) ³⁵	Conventional treatment	Patients at risk of sudden death because of left ventricular systolic dysfunction	\$25–51 per QALY added (in thousands of US \$2005)
Administration of drotrecogin alfa (activated) ³⁴	Usual care	Adults with severe sepsis	\$34–70 per QALY added (in thousands of US \$2003)
Mechanical ventilation and continued aggressive care ³⁴	No mechanical ventilation or mechanical ventilation withheld	Adults with acute respiratory failure	\$33–147 per QALY added (in thousands of US \$2003)
Public access defibrillation (PAD) ³³	Standard emergency medical service agency	Persons in cardiac arrest	\$27–57 per QALY added (in thousands of US \$2003)
Reducing response time for cardiac arrest ³³	Existing emergency medical service agency	Persons in cardiac arrest	\$40–368 per QALY added (in thousands of US \$2003)
Renal dialysis, current practice ³²	Next least costly strategy	Persons with end-stage renal disease	Average of \$129 per QALY added (in thousands of US \$2003)

* Ranges in CERs reflect differences in specifics of the intervention, comparator, target population, and methods for estimating costs and effectiveness across studies.

a Level I trauma center, triaging the less severely injured patients to a lower level of trauma care will result in lower overall costs and increased efficiency of the system overall.

Of ongoing concern is the optimal treatment of older adult trauma patients. Current triage guidelines recommend that advanced patient age should lower the threshold for triage to a trauma center.³⁶ However, the NSCOT study failed to show a significant trauma center effect among patients older than 55 years, leading to an incremental cost per life-year gained of close to \$175,000. Although many would argue this ratio is still within an acceptable range of cost-effectiveness, a better understanding of outcomes among older adults would help to increase both the effectiveness and the efficiency of our systems approach to trauma care.

There are limitations to estimates of both costs and effectiveness. As previously reported, our estimates of lives saved may be conservative because study nontrauma centers were limited to those treating at least 25 major trauma patients annually.¹ Furthermore, 17 of the 51 nontrauma centers had a designated trauma team and 8 had a trauma director. Both of these factors may have biased the results toward a more conservative estimate of the treatment effect. In projecting future life expectancy after the first year posttrauma, we relied on life tables of the general population. Although we adjusted these estimates to reflect a lower life expectancy following severe neurologic injury, we assumed there would be no effect of trauma centers on the risk of dying conditional on 1-year survival. If the benefit of trauma centers extended beyond 1 year, our estimates of cost-effectiveness would be more favorable.

Estimates of 1-year costs excluded expenses related to outpatient pharmacy, durable medical equipment, and hospice care. For some cost categories, we relied on self-reported utilization. Recall bias may result in underreporting of services used, leading to underestimates of true costs.^{37,38} There is no reason to think that, however, the magnitude or direction of the bias would be different for patients treated at trauma centers or nontrauma centers. In projecting life-time treatment costs, we adjusted general population per capita expen-

ditures for specific subgroups of patients but assumed that for patients at similar risk of dying, treatment at a trauma center would not impact costs beyond 1 year.

CONCLUSION

Each year in the United States, >2 million people are hospitalized for treatment of a traumatic injury.³⁹ Years of potential life lost because of injury far exceed those of cancer, heart disease, or stroke.⁴⁰ The impact of injuries on society can be mediated by assuring that the more severely injured are treated at trauma centers. This article provides evidence that this strategy is not only effective but also it is cost-effective. Opportunities exist for improving overall cost-effectiveness by assuring our systems are inclusive in their design, that triage guidelines are effective in matching the right patient with the right facility, and efforts are focused on improving care for the older adult trauma patient.

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DISCUSSION

Dr. Robert C. Mackersie (San Francisco, California): Doctor Cioffi, President-elect Britt, members and guests, I enjoyed this paper very much. It is a pleasure to discuss it. When reading the manuscript for the first time it occurred to me that there are a number of persons in our group far more qualified than I to discuss it and then I realized many of them are coauthors.

This is perhaps one of the most important papers, in terms of long-range impact, to be presented at this meeting. It is an important and logical next-step in analyzing the effectiveness of trauma centers and trauma systems and represents another milestone for Doctor MacKenzie and her group.

It is one of the few studies estimating the value and cost effectiveness of providing trauma care, is based on a more rigorous model than any used in the past, and provides data likely to be critical in our efforts to persuade legislators and the public to invest in trauma systems infrastructure.

Like any study built around an economic model, it necessarily relies on a number of assumptions and in some cases, self-report data.

Rather than taking issue with the details of these assumptions and the study limitations I will try to keep the discussion more at the “30,000-foot level” and pose a number of questions to Doctor MacKenzie.

- Number 1. There are some confounding factors and assumptions such as the life table approach to estimating future QALYs and the resources devoted to trauma centers with 17 out of 51 having trauma team, 8 having trauma medical directors. Can you give us any sense of confidence intervals with these numbers, of cost per quality adjusted life year?
- Number 2. With cost effectiveness appearing to be of less benefit in severely-injured patients, does this study provide an additional cost effectiveness argument for promotion of inclusive systems, i.e., those relying on non-trauma centers for the treatment of low-severity trauma patients versus exclusive systems relying exclusively on higher level trauma centers?
- Number 3. Recognizing that this question sounds terrible, will it be possible to identify a subset of “low-value, low-utility” patients, e.g., those elderly patients with severe multi-system injuries, maybe with traumatic brain injury? Short of a death panel or “throwing granny from the train,” should we be focusing greater efforts on providing more compassionate end-of-life care for this cohort of patients?
- Number 4. With respect to overall costs, how great would the additional impact be on these figures were you to factor in employment benefits to society in patients who return to work as an outcome of trauma center treatment?
- Number 5. From an advocacy standpoint, how do you think we can leverage the data and translate this into improved funding for trauma systems? and,
- Number 6. Pursuant to Doctor Riviera’s comments yesterday, how do we respond to our health care administrator who wants to devote and divert more dollars from tertiary prevention, which is what we do, into primary prevention such as the traffic speed bumps advocated by Doctor Riviera yesterday?

Dr. Ellen J. Mackenzie (Baltimore, Maryland): Thank you very much, Doctor Mackersie, for your comments and your questions.

With regard to your first question about the confidence of our estimates, we did use cost-effectiveness acceptability curves which I did not show here. This is a standard way of quantifying the level of, confidence of our estimates.

From these analyses we can show that the likelihood that the cost effectiveness ratio is \$50,000 or less per life year saved was about 80 percent. For the less-severely injured and the younger patients these estimates are quite robust.

Your comment that some of our non-trauma centers actually look like trauma centers in that they had a trauma team and a trauma medical director I think speaks to the fact that our estimates of the cost effectiveness and the estimates of effectiveness overall are on the conservative side.

With regard to your question about whether or not we should focus our attention on developing more inclusive systems, I would say absolutely yes.

I think these figures again emphasize the need to improve our triage criteria to make sure that those who don't need the resources of a Level I trauma center get directed to a lower level of care.

With regard to your question on death panels – I'll summarize it this way – I personally believe that as a society across the board we need to spend greater efforts on providing more compassionate end-of-life care, absolutely.

However, if you look at the low cost effectiveness among the elderly and the less-severely injured, what is driving that, especially among the elderly, is not the difference in cost but the difference in effectiveness between trauma centers and non-trauma centers.

We showed that in our first NSCOT paper. I still think there is a lot we could do to improve the outcomes of the elderly trauma patient. We need to direct more attention to research in this area.

With respect to whether or not we could show that there was a benefit of trauma center care on getting people back to work.

Unfortunately we haven't been able to show that there is a trauma center effect on getting people back to work. I think that's largely due to the fact that there is so much else going on in the patients' lives after they leave the trauma center that impacts whether or not they can get back to work that we can't really show that link between trauma center care and return to work. So that's an area that we need to move forward with more research.

With regard to how do we leverage these data, I think we're in a great position right now with the current emphasis on cost effectiveness and comparative effectiveness.

These are the kinds of data that Congress is asking for to justify high health care expenditures.

We have the data now. We have the data on effectiveness. We have the data on cost effectiveness. And we need to use this

to more effectively argue for increased efforts at regionalization and more consistent funding of trauma centers.

How do we improve value now and how do we put our results in the context of Doctor Rivara's talk yesterday. That is, how do we justify trauma center cost of \$36,000 versus a speed bump that costs what was it \$3.00.

First of all, you've got to understand that what Doctor Rivara was talking about were costs in low and middle income countries so the costs are lower. But even if you look in the United States there is no question that primary prevention is always going to be more cost effective.

And we need to place more and more emphasis on primary prevention. I think health care reform is only going to work if we pay more attention to primary prevention.

That being said, though, if you look at, for instance, the example of airbags, airbags cost about \$24,000 per life year saved.

So you compare that to our trauma centers I think, again, I think we have a pretty good argument that trauma center care is cost effective.

Dr. Jonathan Groner (Columbus, Ohio): Jon Groner from Columbus, Ohio. I really enjoyed your talk. This is a question about speculation and thinking and not really data.

As a pediatric trauma acute care surgeon, I also take care of neonates. And when we operate on a 700 gram neonate with necrotizing enterocolitis, that baby will leave the hospital with a \$1 million hospital bill, be on oxygen and have long-term disability. And those are strongly funded but pediatric trauma programs not always so much.

Can you speculate on the cost effectiveness of comparing something like pediatric trauma care versus, you know, neonatal care and maybe use some, they use that data to support more funding for pediatric trauma centers?

Dr. Ellen J. Mackenzie (Baltimore, Maryland): So unfortunately the NSCOT study only looked at adults. We did not look at pediatric trauma. I think there is a growing need for doing a similar kind of study for pediatrics.

And I think in a lot of ways the cost effectiveness would be even higher for kids because they have many, many more years of life to live. But I think those studies need to be done and we've got to do them to support cost effective models of pediatric trauma care.