Using a Cost-Benefit Analysis to Estimate Outcomes of a Clinical Treatment Guideline: Testing the Brain Trauma Foundation Guidelines for the Treatment of Severe Traumatic Brain Injury

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Background: A decade after promulgation of treatment guidelines by the Brain Trauma Foundation (BTF), few studies exist that examine the application of these guidelines for severe traumatic brain injury (TBI) patients. These studies have reported both cost savings and reduced mortality.

Materials: We projected the results of previous studies of BTF guideline adoption to estimate the impact of widespread adoption across the United States. We used surveillance systems and national surveys to estimate the number of severely injured TBI patients and compared the lifetime costs of BTF adoption to the current state of treatment.

Results: After examining the health outcomes and costs, we estimated that a substantial savings in annual medical costs ($262 million), annual rehabilitation costs ($43 million) and lifetime societal costs ($3.84 billion) would be achieved if treatment guidelines were used more routinely. Implementation costs were estimated to be $61 million. The net savings were primarily because of better health outcomes and a decreased burden on lifetime social support systems. We also estimate that mortality would be reduced by 3,607 lives if the guidelines were followed.

Conclusions: Widespread adoption of the BTF guidelines for the treatment of severe TBI would result in substantial savings in costs and lives. The majority of cost savings are societal costs. Further validation work to identify the most effective aspects of the BTF guidelines is warranted.

Key Words: Cost benefit, Traumatic brain injury, TBI, Treatment guidelines, Acute care, Societal impact, Rehabilitation, Glasgow Outcome Score.

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Traumatic brain injury (TBI) is a major acute injury problem in the United States resulting in disabling conditions and long-term societal costs. The Centers for Disease Control and Prevention (CDC) reports that at least 1.4 million Americans sustain a TBI each year.[1] Of this group, 50,000 will die, and many of those who survive will join the approximately 5.3 million Americans currently living with TBI-related disabilities.[1,2] A TBI can produce a broad array of functional changes of various intensities and combinations that affect cognition, sensation, emotions, and speech.[3,4] These disabilities often require long-term care or lifelong assistance to perform activities of daily living. The annual economic burden of TBI in the United States was approximately $60 billion in 2000.[5] To reduce mortality and morbidity, and to address the wide variation in treatment practice,[6] the Brain Trauma Foundation (BTF) developed clinical treatment guidelines for prehospital and inhospital care of severe TBI in 1995.[7,8] These guidelines focus on severely injured adults with an initial Glasgow Coma Scale (GCS) score of ≤ 8.[7,8] Although disseminated widely, the guidelines had only been adopted by an estimated 33% of US trauma centers 5 years after promulgation.[9]

There are few published evaluations of the costs of TBI treatments in acute care settings.[10] Efforts to evaluate summary costs for this injury are important because of its prevalence and potential for lifelong disability. Recent literature has cited low physician compliance with various existing treatment guidelines,[11] and described the barriers to adoption of guidelines that physicians face within hospitals and other healthcare settings.[11,12] To evaluate an existing guideline in accordance with *CDC Acute Injury Care Research Agenda: Guiding Research for the Future*,[13] we conducted a cost-benefit analysis to determine the effectiveness of adopting the BTF inhospital guidelines for the treatment of adults with severe TBI. Because the BTF guidelines have a number of multistep recommendations, the effectiveness of the entire set of recommendations was assessed as a group, and not considered individually.

METHODS

Literature Search

To perform a cost-benefit analysis on this topic, a wide array of materials were identified and evaluated. There was no single source or type of literature that provided the majority of the data elements required. Table 1 lists the variables

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Table 1 Determination of Model Variables

Node	Variable	Baseline Value	Original Source	Modification
Hospital admission for TBI	(a) Number of cases of severe TBI cases resulting in hospital admission beyond 1 d	23,265	NHDS[20]	Total number of TBI cases 12 yr and older admitted to the hospital adjusted for proportion assumed to be severe from 1999 CDC TBI Surveillance Data[21]
Current state, GOS 4–5	(c1) Proportion	0.35	Fakhry et al.,[14] Palmer et al.[15]	Averaged proportion in baseline group with GOS 4–5 outcomes from two studies
	(c1) Direct medical costs	$36,030	Finkelstein et al.[5]	Costs adjusted for GOS 4–5 using length of stay from 1999 CDC TBI Surveillance Data. Calculated rehabilitation costs removed (see Rehabilitation Costs)
	(c4) Rehabilitation (proportion)	0.03	CTBIFRS[22]	Proportion with GOS 4–5 entering rehabilitation
	(c4) Rehabilitation costs	$11,422	Kreutzer et al.,[24] CTBIFRS[22]	Average cost per day multiplied by average number of rehabilitation days for GOS 4–5
	(c9) Societal costs	$3,282	Finkelstein et al.[5]	Only short-term wage and production loss costs (for hospitalizations) used. It was assumed that rehabilitation reduced social impact by 20%
	(c10) Societal costs	$4,103	Finkelstein et al.[5]	Only short-term wage and production loss costs (for hospitalizations) used
Current state, GOS 2–3	(c2) Proportion	0.34	Fakhry et al.,[14] Palmer et al.[15]	Averaged proportion in baseline group with GOS 2–3 outcomes from two studies
	(c2) Direct medical costs	$92,599	Finkelstein et al.[5]	Costs adjusted for GOS 2–3 using length of stay from 1999 CDC TBI Surveillance Data.[21] Calculated rehabilitation costs removed (see Rehabilitation Costs)
	(c6) Rehabilitation (proportion)	0.25	CTBIFRS[22]	Proportion with GOS 2–3 entering rehabilitation
	(c6) Rehabilitation costs	$52,217	Kreutzer et al.,[24] CTBIFRS[22]	Average cost per day multiplied by average number of rehabilitation days for GOS 2–3
	(c11) Societal costs	$59,738	Finkelstein et al.[5]	Long- and short-term wage and production loss costs (for hospitalizations) used. It was assumed that rehabilitation reduced social impact by 20%
	(c12) Societal costs	$74,673	Finkelstein et al.[5]	Long- and short-term wage and production loss costs (for hospitalizations) used
Current state, GOS 1	(c3) Proportion	0.30	Fakhry et al.,[14] Palmer et al.[15]	Averaged proportion in baseline group that died after enrollment from two studies
	(c3) Direct medical costs	$53,692	Finkelstein et al.[5]	Costs adjusted for GOS 1 using length of stay from 1999 CDC TBI Surveillance Data[21]
	(c8) Societal costs	$1,003,140	Finkelstein et al.[5]	Long-term wage and production loss costs (for deaths) used
BTF adoption, GOS 4–5	(b1) Proportion	0.66	Fakhry et al.,[14] Palmer et al.[15]	Averaged proportion in adoption group with GOS 4–5 outcomes from two studies
	(b1) Direct medical costs	$36,030	Finkelstein et al.[5]	Costs adjusted for GOS 4–5 using length of stay from 1999 CDC TBI Surveillance Data.[21] Calculated rehabilitation costs removed (see Rehabilitation Costs)
	(b4) Rehabilitation (proportion)	0.03	CTBIFRS[22]	Proportion with GOS 4–5 entering rehabilitation
	(b4) Rehabilitation costs	$11,422	Kreutzer et al.,[24] CTBIFRS[22]	Average cost per day multiplied by average number of rehabilitation days for GOS 4–5
	(b9) Societal costs	$3,282	Finkelstein et al.[5]	Only short-term wage and production loss costs (for hospitalizations) used. It was assumed that rehabilitation reduced social impact by 20%
	(b10) Societal costs	$4,103	Finkelstein et al.[5]	Long- and short-term wage and production loss costs (for hospitalizations) used
BTF adoption, GOS 2–3	(b2) Proportion	0.19	Fakhry et al.,[14] Palmer et al.[15]	Averaged proportion in adoption group with GOS 2–3 outcomes from two studies
	(b2) Direct medical costs	$92,599	Finkelstein et al.[5]	Costs adjusted for GOS 2–3 using length of stay from 1999 CDC TBI Surveillance Data.[21] Calculated rehabilitation costs removed (see Rehabilitation Costs)

Table 1 Determination of Model Variables (continued)

Node	Variable	Baseline Value	Original Source	Modification
	(b6) Rehabilitation (proportion)	0.25	CTBIFRS[22]	Proportion with GOS 2–3 entering rehabilitation
	(b6) Rehabilitation costs	$52,216	Kreutzer et al.,[24] CTBIFRS[22]	Average cost per day multiplied by average number of rehabilitation days for GOS 2–3
	(b11) Societal costs	$59,738	Finkelstein et al.[5]	Only short-term wage and production loss costs (for hospitalizations) used. It was assumed that rehabilitation reduced social impact by 20%
	(b12) Societal costs	$74,673	Finkelstein et al.[5]	Long- and short-term wage and production loss costs (for hospitalizations) used
BTF adoption, GOS 1	(b3) Proportion	0.15	Fakhry et al.,[14] Palmer et al.[15]	Averaged proportion in adoption group that died after enrollment from two studies
	(b3) Direct medical costs	$53,692	Finkelstein et al.[5]	Costs adjusted for GOS 1 using length of stay from 1999 CDC TBI Surveillance Data[21]
	(b8) Societal costs	$1,003,140	Finkelstein et al.[5]	Long-term wage and production loss costs (for deaths) used

Displayed numbers are subject to rounding errors. 2002 US Dollar amounts.

used and the sources from which the variables were extracted. To locate clinical studies of BTF adoption in the United States, literature searches were performed in MEDLINE, EMBASE, and EconLit for the period 1995 to 2006. During this period, five US studies regarding the effect of BTF guideline adoption on patient outcomes were published and indexed.[14–18] From this set of five studies, two[14,15] provided estimates of the effect size because they contained adequate health outcome measures needed for the cost-benefit analysis.

Definitions

For the purposes of this study, six specific terms require definition. First, a Decision Analysis Model is a method used to evaluate the probability of a number of events occurring. It is typically depicted in graphic form as a *probability tree* with key data elements and decisions appearing at certain junctures, or nodes, leading to a declared potential outcome along a given *branch*. Second, the phrase BTF Adoption is used to describe the state of medical care as it relates to hospital implementation of the BTF guidelines. Recognizing that a portion of severely injured TBI patients will not be candidates for the BTF guidelines because of comorbidities or extenuating circumstances, the assumption of 80% compliance was considered to be fully compliant. Third, the state of current US medical care as it related to the BTF guidelines is called Current State in the model. Based on the literature found, the compliance rate was set at 33%.[9] Fourth, within the context of this analysis, Societal Costs describes those costs that represent lifetime work loss costs (both professional and household) resulting from permanent disability, plus the cost resulting from temporary disability. Fifth, Rehabilitation Costs represent the costs expended at rehabilitation centers. Finally, Direct Medical Costs are defined for this model as all costs associated with the medical treatment of the injury throughout the lifetime of the patient; this includes prehospital care, acute medical care, readmissions and follow-up visits, and nursing home care.

Study Population From US Population Projections

Based on the exclusion criteria used by the two studies referenced in our model,[14,15] the number of severely injured TBI patients aged 12 years or older that did not die within 1 day of hospital admission was calculated to determine the number of cases to apply to the model. In developing this number we attempted to duplicate the methods used in previous research on BTF application.[14,15] We applied the International Classification of Diseases Clinical Modification diagnosis codes found in the CDC Traumatic Brain Injury Case Definition[19] to the 2002 National Hospital Discharge Survey (NHDS) public use dataset;[20] this yielded the number of TBI patients aged 12 or older who were admitted to hospitals in the United States (n = 226,974). The NHDS is a national probability survey designed to meet the need for information on characteristics of inpatients discharged from non-Federal short-stay hospitals in the United States. We then used the 1999 CDC TBI surveillance data, collected from 13 States (Alaska, Arkansas, Arizona, Colorado, Louisiana, Maryland, Minnesota, Nebraska, New York, Oklahoma, Rhode Island, South Carolina, and Utah), to calculate the percent of severely injured TBI patients aged 12 and older who did not die within 1 day after hospital admission (10.25%). By defining a severe TBI as a patient having a GCS of 3 to 8 or a low Level of Consciousness (as defined by CDC),[19] these figures were multiplied, resulting in a total of 23,265 patients as the estimate of the number of people that could benefit from using BTF guidelines during their hospitalization. This population number (23,265) was used for both probability trees to compare different costs and health outcomes.

Probability of Health Outcomes

The Glasgow Outcome Scale (GOS) score was the key outcome variable in determining outcomes between Current State and BTF Adoption. A GOS score of 4 (moderate disability) and 5 (good recovery) were collapsed into one group, as was the GOS score of 2 (vegetative) and 3 (severely disabled). The GOS outcomes in the probability tree were calculated by using the nonweighted average of the GOS outcomes in previous studies.[14,15] In determining the expected proportion of GOS outcomes that were the result of current treatment we used the average GOS outcomes for the first cohort (low BTF compliance) in one study[14] and the pre-BTF compliant GOS group in the second study.[15]

Medical Costs and Societal Costs

Direct medical and societal costs for TBI mortality and morbidity were calculated from *The Incidence and Economic Burden of Injuries in the United States*.[5] This book includes data tables for the direct medical costs, and long- and short-term wage loss costs (societal costs) for TBI by type and disposition (e.g., death, hospitalization, emergency department, outpatient, doctor's office). For our study, only costs for severe TBI cases resulting in death or hospitalization were used. For all costs discussed, amounts were converted from year 2000 dollars to 2002 dollars so that estimates would be made using comparable years for the studies chosen for this cost-benefit analysis.

On average, the direct medical cost for severe TBI in 2002 dollars was $65,600 per patient.[5] Using the 1999 CDC TBI Surveillance System,[19] we calculated the length of stay for each of the GOS groups. The proportion of each GOS group occurring in the current state was obtained from the cited literature: 0.3515 for GOS score 4 to 5 group, 0.3445 for GOS score 2 to 3 group, and 0.304 for GOS score 1.[14,15] The average cost per day was $4,330.03, determined by using the estimated length of stay, for each GOS score level and the proportion of patients expected to have each GOS score level and outcome, and the total cost in the Current State. Multiplying the cost per day by the average length of stay for each GOS score level, the estimated direct medical costs used in the models were obtained: $36,372 for the GOS score 4 to 5 group, $105,653 for GOS score 2 to 3 group, and $53,692 for GOS score 1 group. These costs were then reduced by the estimated amount of rehabilitation costs, resulting in $36,030 for the GOS score 4 to 5 group and $92,599 for GOS score 2 to 3 group.

Societal costs for TBI mortality were calculated by summing long-term wage and production loss costs,[5] resulting in an estimated $1,003,140 per deceased person (2002 dollars). For nonfatal TBI, separate costs were calculated for those persons with a GOS score 2 to 3 and GOS score 4 to 5. For persons with GOS score 2 to 3, short- and long-term wage and production loss costs were included to produce a total average cost of $74,673 per person. For those persons in the GOS score 4 to 5 group, it was assumed that they were healthier and able to return to work sooner. Thus, for these persons, only short-term wage and production loss costs were included to produce a total average loss cost of $4,103 dollars per person. If a person received rehabilitation, societal costs were reduced by 20% based on the presumed effectiveness of the rehabilitation. An inflation calculator available from the US Department of Labor, Bureau of Labor Statistics was used to adjust for inflation, for the target year of 2002.[21]

Rehabilitation Costs

The proportion of patients that entered into rehabilitation was calculated using the Colorado Traumatic Brain Injury Follow-Up Registry System (CTBIFRS) public use dataset.[22] The proportion of people entering rehabilitation was calculated to be 25% for the GOS score 2 to 3 group, which is similar to previous reports of 17% to 21%.[23] The number of days of rehabilitation was also obtained from CTBIFRS[22] and other research on length of stay in a rehabilitation setting.[24] The average number of days of rehabilitation was 29;[24] this was proportionally adjusted using the ratios of days of rehabilitation between the GOS score 2 to 3 group and the GOS score 4 to 5 group available in the CTBIFRS (year 1996).[22] The net result was 32 days of rehabilitation for the GOS score 2 to 3 group and 8 days of rehabilitation for the GOS score 4 to 5 group. The average cost for rehabilitation per day was $1,423.15 in 1996,[24] which was adjusted to be $1,631.77 in 2002 using an inflation calculator available from the US Department of Labor, Bureau of Labor Statistics.[21]

Guideline Implementation Costs

Labor and staff training were the main costs of managing a set of protocols for patient treatment. Adherence to the BTF guidelines does not require substantial additional fixed costs for a typical Level I trauma center; exceptions include more frequent use of intracranial pressure (ICP) monitoring, and additional laboratory tests. In an effort to evaluate guideline implementation costs, we discussed guideline adherence with three expert sources (J. Ghajar, July 2005, oral communication; S. Fakhry, January 2006, oral communication; D. Wright, March 2006, oral communication). After considering the personnel costs for training, and increased patient management costs because of more frequent use of ICP monitors, we made a conservative estimate that implementation of the BTF guidelines would add 5% to the total medical costs. Therefore, the total estimated implementation costs would be $2,618 per person, or $61 million for the United States.

The Decision Analysis Model and Development of the Probability Tree

A decision analysis model illustrating the likelihood of potential states for TBI treatment was developed, and included the costs from the time of hospital admission until death or discharge from rehabilitative treatment. This allowed for documenting costs and outcomes from hospital admission until a person died or reentered society. Firm estimates on the number of people potentially impacted by BTF guideline application could not be obtained on prehospital or emergency department treatment because existing literature only focused on acute care among hospitalized patients. Neither published analyses nor data sets using prehospital data regarding BTF guideline compliance

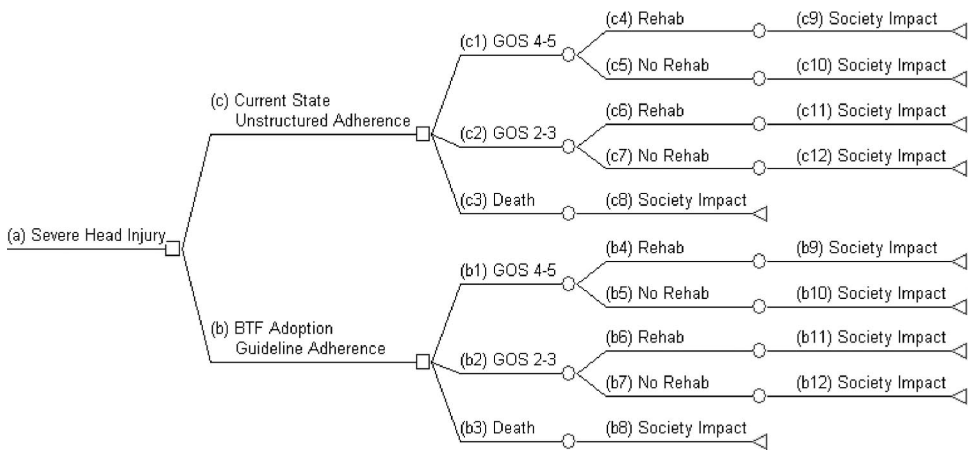

Fig. 1. *Probability trees comparing current state with BTF adoption.*

were found. A probability tree was created to model the potential states and outcomes. The Current State portion of the tree represents the estimated current state of the treatment of severely injured TBI patients with outcomes of costs and mortality. The BTF Adoption portion of the probability tree uses a similar design, but emulates the outcomes reported in two studies with high BTF guideline compliance.[14,15] Using a case count estimated from the NHDS,[20] the Current State branches of the probability tree were compared with the branches of the BTF Adoption portion of the tree to determine differences in costs and health outcomes.

The model and tree diagram were produced using TreeAge software (Fig. 1). The tree design allows for the inputs of probability of health outcome and probability of rehabilitation. The GOS score was used to determine health outcome and define the extent of disability after hospitalization. For analysis, one group was composed of GOS score 5 (good recovery) and GOS score of 4 (moderate disability); one group was composed of GOS score of 3 (severe disability) and GOS score of 2 (vegetative state). For those who died in hospital, a GOS score of 1 (death) was also included. Costs were entered for each branch within a probability tree. We included estimated direct medical costs, rehabilitation costs, and overall costs to society. All of these costs and probability of outcomes were multiplied by the total number of patients that could be impacted by application of BTF guidelines, based on the average outcomes of published work in this area.[14,15]

RESULTS

Table 2 presents the costs associated with BTF guideline adoption. By comparing the different outcomes from the two probability trees, the application of the BTF guidelines resulted in an estimated savings of 3,607 lives using 2002 data. This is a 15% decrease in deaths for severely injured TBI patients 12 years or older who were hospitalized and survived 1 day of hospital admission during the year 2002. These improved outcomes reveal that one is twice as likely to survive if BTF guidelines are followed. The proportion of patients with good outcomes (GOS score 4–5) increased substantially from 35% to 66%, and the proportion of patients with poor outcomes (GOS score 2–3) decreased from 34% to 19%.

Before implementation costs, the higher proportion of healthier people would result in an annual savings in medical costs ($262 million) and reduced rehabilitation costs ($43 million). In addition to saving lives (3,607 people annually), a major cost savings was realized because of the greatly reduced societal costs associated with fewer deaths ($3.84 billion). Once the intervention costs are added in ($61 million), the estimated annual total cost savings of implementing BTF guidelines is substantial ($4.08 billion).

As reported in Table 3, the implementation cost was estimated to be $2,618, and the reduction in medical costs was $11,280 per person. This savings of $8,662 represents a 430% return on investment of medical costs. The large savings primarily resulted from increased proportion of patients with higher GOS scores, which resulted in substantially fewer costs.

If we assume partial BTF compliance produces some benefits, we can predict the number of lives and amount of costs saved at various levels of BTF compliance. Application of a single BTF guideline (e.g. ICP monitoring) would likely produce some measurable benefit. Although these data do not allow

Table 2 **Overall Cost Savings and Lives Saved Resulting From Adoption of BTF Guidelines—Total Costs**

	Deaths	Direct Medical Costs	Rehabilitation Costs	Societal Costs	Implementation Costs	Total Costs
BTF adoption	3,466	$ 1,154,116,956	$ 64,008,683	$ 3,859,102,789	$ 60,906,282	$ 5,138,134,710
Current state	7,073	$ 1,416,538,024	$ 107,428,632	$ 7,696,680,328	$ 0	$ 9,220,646,983
Difference	3,607	$ 262,421,068	$ 43,419,949	$ 3,837,577,538	$ 60,906,282	$ 4,082,512,273

Calculated medical costs probabilities are subject to rounding errors.

Table 3 Overall Cost Savings and Lives Saved Resulting From Adoption of BTF Guidelines—Costs per Person

	Deaths	Direct Medical Costs	Rehabilitation Costs	Societal Costs	Implementation Costs	Total Costs
BTF adoption	3,466	$ 49,607	$ 2,751	$ 165,876	$ 2,618	$ 220,853
Current state	7,073	$ 60,887	$ 4,618	$ 330,827	$ 0	$ 396,331
Difference	3,606	$ 11,280	$ 1,866	$ 164,951	($ 2,618)	$ 175,479

Calculated medical costs probabilities are subject to rounding errors.

for the evaluation of each individual BTF guideline, if we assume compliance is directly correlated with beneficial outcomes, then an increase from the current 33% compliance to 50% compliance would result in saving an estimated 989 lives in the United States. Using the same approach, 80% compliance yields an estimated 3,607 lives saved (Fig. 2) if the BTF guidelines were to be applied across the United States.

Because the proportion of good outcomes increased substantially after high BTF compliance, one key finding is that a smaller proportion of the population would have a severe disability or be in a vegetative state (from 34% to 19%).

Sensitivity Analysis

One of the biggest differences in outcomes is the number of expected deaths. Because these differences come from uncertain sources, a sensitivity analysis was performed on these variables. A sensitivity analysis allows an assessment of the effect that data uncertainty may have on the overall lives saved estimate. Monte Carlo simulations are based upon random sampling of variables from distributions using individual trial data. A Monte Carlo analysis[25] using a probabilistic sensitivity sampling method, based on 1,000 simulations, indicates that the 95% confidence limits for the estimated number of lives saved upon widespread guideline adoption is between 2,904 and 4,326.

DISCUSSION

The BTF guidelines were put forth to improve the quality of care of TBI patients. The overall results reported in this study could result in a substantial reduction in mortality and simultaneously reducing medical, rehabilitation, and societal costs. If these results are representative across the United States, severely injured TBI patients could also enjoy an enhanced quality of life. With a larger proportion of healthier people, some burden on families left caring for disabled TBI patients would likely be reduced. The positive impact on society support systems is also considerable.

After a decade following promulgation, the lack of published evidence regarding the BTF guidelines is remarkable when compared with the validation and adoption studies conducted to assess other treatment guidelines. For example, the American College of Cardiology and American Heart Association's guidelines for treatment of suspected acute myocardial infarction[26] with thrombolytic agents produces over 700 articles in Medline;[27] the use of these drugs for stroke produces over 500 articles.[27]

Another finding of interest was that none of the published US studies[14–18] cited an outside funding source. These studies were completely accomplished with resources within the respective institutions. It is concerning that guidelines with such potential impact for patient care and economic benefit have not been funded, studied, and published more frequently.

A frequently overlooked feature of TBI in the health care arena is long-term disability. The impact of a neurologic disability on family, work, and society is noteworthy. The estimated medical costs savings per TBI patient ($11,280) was a fraction of the estimated costs to society ($164,951). As the focus of acute care is on saving lives, it is important to remember that improvement in health outcomes results in a lower financial burden of injury on society; these costs last a lifetime. This study attempts to capture the long-term disability implications of severe TBI.

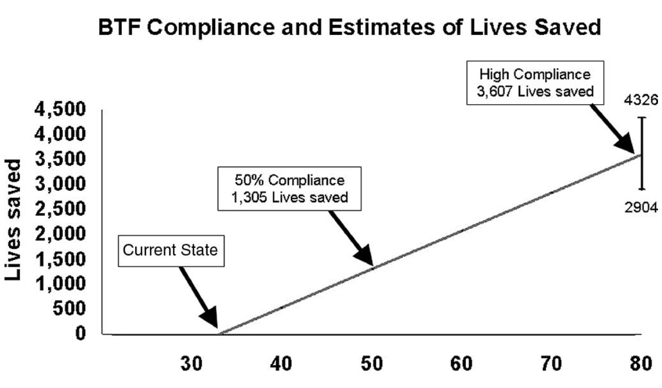

Fig. 2. *Estimated number of lives saved based on brain trauma foundation guidelines compliance.*

Limitations

The proportion of GOS scores, the main variable for our probability tree models, was derived from US research found in the published literature. Because successful publication is frequently based on the finding of significant differences, overestimation of the benefits of BTF adoption is a possibility.

National surveys and other representative datasets provided us with good estimates of the number of people that could be impacted. It is important to note that the patient samples used by other researchers[14,15] are not likely to be representative of all severely injured TBI patients in the United States. The sample of patients used by these researchers had very low GCS scores. Given the difficulties with accurate initial GCS scoring (e.g., effects of alcohol and drug intoxication,[28] endotracheal intubation, use of neuromuscular paralytic agents) determinations of the number of people that could benefit from BTF compliance could be over-estimated.

None of the published studies[14–18] was based on random selection of subjects. Additionally, when combining the experience of other researchers, we found some features of the samples could not be easily reconciled. One study used a population of 8 years and older,[15] whereas another study used a population of 14 years and older.[14] We used a median population of 12 years and older to generate the estimates needed to run the cost-benefit analysis. In assessing the GOS scores of the Current State, we relied on the average outcome measures reported in existing research.[14,15]

We assumed costs for a day of hospitalization to be equal for patients in the GOS score 2 to 3 and GOS score 4 to 5 groups. Patients with GOS scores of 2 and 3 will require more intensive nursing care and monitoring, and would therefore be expected to have higher hospital costs. The major finding in this study is that the proportion of patients that had a health outcome of GOS score 4 to 5 nearly doubled (35% to 66%). Assuming this to be true, our cost savings estimates are conservative. Other factors such as patients having other significant injuries may skew these results.

Having observed the savings in terms of lives and costs after BTF guideline adoption, it is important to note that we do not know whether the documented successes of these practices at the reporting institutions[14,15] were because of a specific recommendation within the overall BTF guidelines. Also, it is possible that some portion of reported positive outcomes may have occurred as a result of improvements in trauma center management or increased staff expertise[23] once a set of protocols were implemented and consistently monitored.

Treatment following the BTF guidelines could be more beneficial for people with the lowest GCS scores; the effect of strict application of the guidelines on less severely injured TBI patients (GCS of 6–8) is unknown. Because 32% of severely injured TBI patients in the United States[19] do not have GCS scores of 3 to 5, if BTF guideline compliance is more effective with more severely injured people, then these estimates of lives saved may be overstated.

In preparing these estimates, we attempted to mirror the samples used in other research.[14,15] Unfortunately, we were unable to include analyses of BTF guideline compliance in the prehospital or emergency department settings. As a result, our estimates of lives saved may be understated.

CONCLUSION

The purpose of this study was to apply a cost-benefit analysis of adoption and compliance of the BTF guidelines for the treatment of adults with severe TBI. While it is recognized that adoption and compliance to any clinical guideline is contingent upon institutional resources, policies, and practices, this initial cost-benefit study demonstrates that even partial compliance to the BTF guidelines can likely produce substantial savings in lives and dollars. Although we examined many studies, our analysis was based on limited available data. The findings suggest that the impact of BTF guideline adoption on public health in the United States could be profound by decreasing mortality for adults with severe TBI, in addition to improving health outcomes.

Dual and interdependent effects of better health outcomes and reduced costs of the magnitude found in this analysis are rarely cited. We are hopeful that these results lead to increased adoption and compliance of the BTF guidelines, improved outcomes for severely injured TBI patients, and evaluation of other existing guidelines for the care of the acutely injured.

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