

RESEARCH ARTICLE

# The aggressiveness of neurotrauma practitioners and the influence of the IMPACT prognostic calculator

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## Abstract

Published guidelines have helped to standardize the care of patients with traumatic brain injury; however, there remains substantial variation in the decision to pursue or withhold aggressive care. The International Mission for Prognosis and Analysis of Clinical Trials in TBI (IMPACT) prognostic calculator offers the opportunity to study and decrease variability in physician aggressiveness. The authors wish to understand how IMPACT's prognostic calculations currently influence patient care and to better understand physician aggressiveness. The authors conducted an anonymous international, multidisciplinary survey of practitioners who provide care to patients with traumatic brain injury. Questions were designed to determine current use rates of the IMPACT prognostic calculator and thresholds of age and risk for death or poor outcome that might cause practitioners to consider withholding aggressive care. Correlations between physician aggressiveness, putative predictors of aggressiveness, and demographics were examined. One hundred fifty-four responses were received, half of which were from physicians who were familiar with the IMPACT calculator. The most frequent use of the calculator was to improve communication with patients and their families. On average, respondents indicated that in patients older than 76 years or those with a >85% chance of death or poor outcome it might be reasonable to pursue non-aggressive care. These thresholds were robust and were not influenced by provider or institutional characteristics. This study demonstrates the need to educate physicians about the IMPACT prognostic calculator. The consensus values for age and prognosis identified in our study may be explored in future studies aimed at reducing variability in physician aggressiveness and should not serve as a basis for withdrawing care.

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## Introduction

Advancement in traumatic brain injury (TBI) care has lagged behind that in other fields [1, 2]. Unfortunately, we remain without a pharmacologic agent that improves outcome from TBI, although progress is being made in elucidating management strategies that benefit patients with TBI. In particular, the development of evidence-based management guidelines—first published in 1996 [3]—have helped to improve and standardize TBI care. Adherence to published guidelines has been associated with improved outcomes [4]. The development and extensive validation of the International Mission for Prognosis and Analysis of Clinical Trials in TBI (IMPACT) prognostic calculator (<http://www.tbi-impact.org/?p=impact/calc>) has also been an important advance [5]. According to external validation, it accurately predicts outcomes for TBI patients in >80% of cases.

A very important aspect of TBI care that has been the subject of little study is the decision about when to provide aggressive care and when to pursue comfort care or withdrawal of care. In our experience, substantial variation exists in practitioner perceptions of patient outcomes [6] as well as their attitudes and decisions with regards to the pursuit of aggressive care. Of particular concern is when nihilism robs a patient of a reasonable chance of a good outcome. Here, the IMPACT prognostic calculator offers the opportunity to bring greater objectivity to level-of-care decisions and the possibility of greater standardization in provider aggressiveness.

Practitioner familiarity with the IMPACT calculator is unknown [7, 8]. With this in mind, we performed an international, multidisciplinary survey of practitioners who provide acute care to TBI patients with the goal of understanding familiarity with and current uses of the IMPACT prognostic calculator. We sought to determine whether there is a consensus level at which the chance of death or a poor outcome would cause physicians to seriously consider nonaggressive care. Moreover, given that age is the strongest predictor of outcome from TBI [9], we sought to determine if there is a consensus age at which nonaggressive care is strongly considered by practitioners. We additionally explored physician and institutional predictors of physician aggressiveness with the goal of better understanding provider decisions.

## Materials and methods

### Surveys

We conducted a survey of neurosurgeons and other practitioners who provide care to TBI patients in the acute phase (S1 Survey). The American Association for the Surgery of Trauma (AAST) distributed the survey to its members, who are predominantly acute care surgeons, surgical intensivists, and general surgeons. The University of Utah Institutional Review Board serves to ensure protection of human research subjects in research completed by University of Utah investigators. An anonymous survey of physician opinion is exempt from requiring approval of our institutional review board as it poses no risk to the unidentifiable, anonymous respondents who completed our survey. Voluntary completion of the survey was considered equivalent to provision of informed consent.

The 19-question survey we developed was administered by email in October of 2015. The questions were developed to understand current familiarity with and use of the IMPACT prognostic calculator and to investigate how this was influenced by respondents' experience and practice environments. Questions also explored threshold values of age as well as chance of death or poor outcome that would prompt a serious consideration of withdrawal of care. Survey responses were collected and managed using the Research Electronic Data Capture application (REDCap, Nashville, Tennessee) [10]. We accepted responses during a three-month period (October–December 2015); non-responders were provided with two reminders during this period.

## Statistical analysis

Responses were exported from REDCap electronic data capture tool [10]. Statistical analysis was performed using SPSS version 23 (International Business Machines Corporation, Armonk, New York) and STATA version 12 (StataCorp LP, College Station, Texas). Poisson regression was used for count data; analysis of variance and chi-squared tests were used to analyze means. A Bonferroni correction was done for multiple comparisons. Binomial logistic regression was used for discrete choice data and to determine associations with other features. Error bars represent standard error in all cases.

## Results

### Characteristics of respondents and their institutions

A total of 154 responses to our survey were received and analyzed. Characteristics of respondents are shown in Table 1. A majority of respondents were general surgeons (71.4%) followed by neurosurgeons (23.4%). A minority were practitioners of other subspecialties who provide acute TBI care (5.2%). Most respondents (80.5%) work at a Level I trauma center, whereas 14.9% work at a Level II trauma center and 4.5% at a Level III center. The volume of moderate and severe TBI reportedly treated by respondents is demonstrated in Fig 1. A majority (58.8%) of the respondents said that they provide care for moderate to severe TBI “very frequently” and 27.5% said that they provide care “frequently” (Fig 1C). Respondents who provide care “less frequently,” “occasionally,” “rarely,” and “never” made up the remaining 13.7% of the cohort. Just over half (54.6%) of the respondents work for institutions with separate surgical critical care and neurocritical care units, whereas the remaining institutions had a single critical care unit providing care to the acutely brain injured. Respondents reported being in practice a mean of 16.5 years (median 15, range 1–40) (Fig 1D).

### Familiarity with and use of the IMPACT prognostic calculator

Approximately half of surveyed providers (50.3%) answered that they were aware of the online IMPACT calculator. Practice specialty was significantly associated with awareness of the IMPACT calculator, with 69.4% of neurosurgeons reporting awareness of the calculator as compared with 42.2% of general surgeons ( $p = 0.014$ , Fig 2A). Among those aware of the calculator, 45.5% said that they never use it in the management of brain-injured patients, 5.2% said that they often use it, and 48.1% said that they sometimes use it ( $p = 0.236$ , Fig 2B).

Of 42 providers who at least occasionally used the calculator, 88.1% stated that it had some influence on their care of patients (57.1% said that it had a “mild influence” on their care of patients, 23.8% “moderate influence,” and 7.1% significant influence) (Fig 2C). All of those respondents reporting that the IMPACT calculator had “significant influence” on care (7.1%) had fewer than 10 years in practice. Neurosurgeons reported significantly more often (33.3%) that the IMPACT calculator had a “moderate influence” on their care of patients, whereas only

**Table 1. Characteristics of survey respondents.**

Characteristic	Proportion of Respondents (%)
Neurosurgeons	23.4
General Surgeons	71.4
Other	5.2
Practicing in America	83.1
Practicing Outside America	9.1
Did Not Answer	7.8

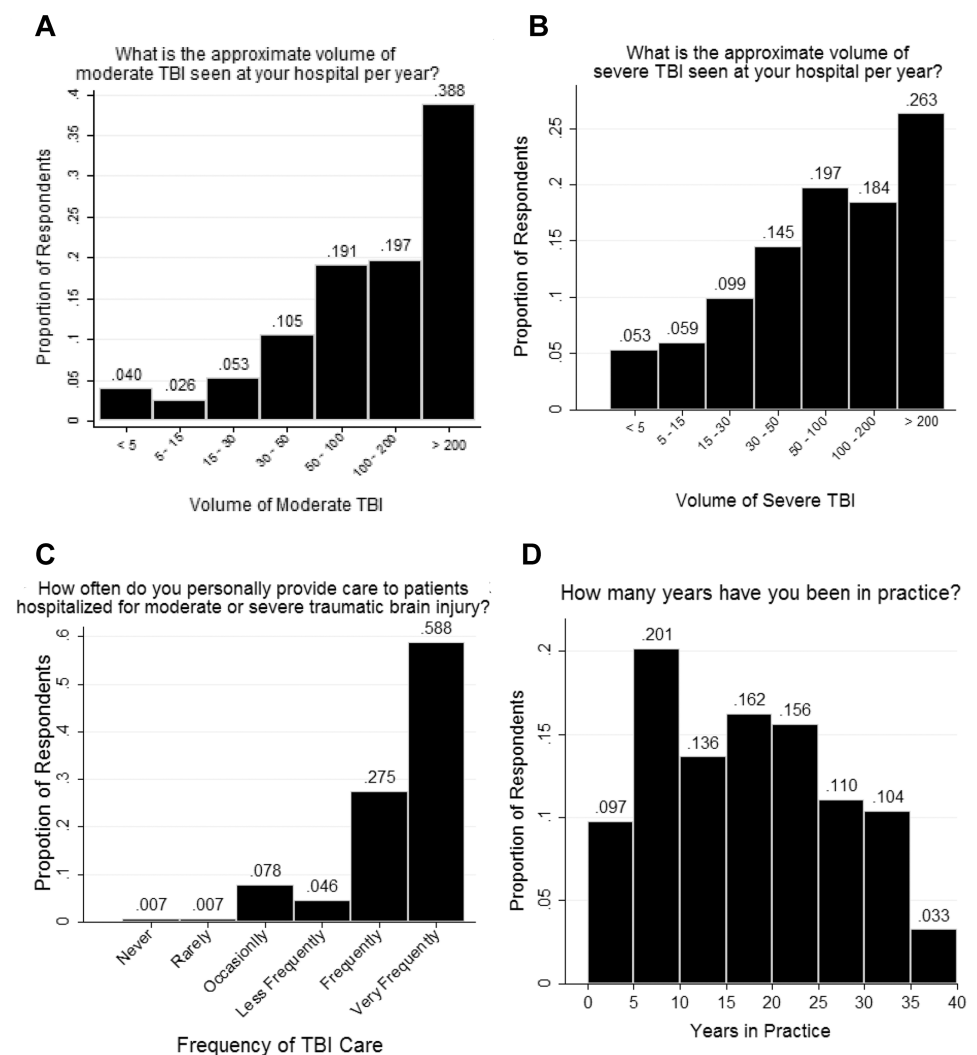
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18.5% of general surgeons responded saying that the calculator had the same influence ( $p = 0.010$ , Fig 2C).

For those who were influenced by the calculator, a large majority (91.9%) stated that it helped improve communication about prognosis with family, 21.6% of physicians said that it led them to pursue more aggressive care, and 27.0% indicated they proceeded more quickly to a lower level of care (respondents could select more than one option, Fig 2D). Over 20% stated that the IMPACT predictions influenced care in more than one way. Binomial logistic regression demonstrated that specialty was not significantly associated with the way IMPACT predictions influenced care ( $p = 0.181$ , Fig 2D).

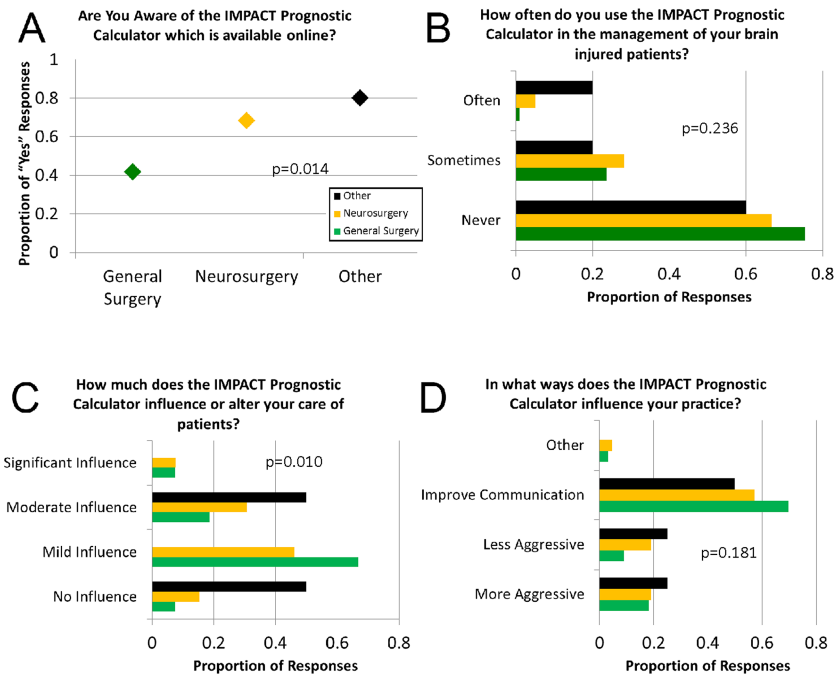
### Prognostic calculation and physician aggressiveness

Only 16.7% of neurosurgeons and 14.0% of general surgeons indicated that age has no influence on their decision to pursue aggressive care, and typically respondents indicated that



**Fig 1. Responses to survey questions 7, 6, 8, and 2 (S1 Survey, Supplemental Digital Content 1) are presented in A, B, C, and D, respectively. A)** Reported volume of moderate TBI cared for at the respondents' institutions per year. **B)** Reported volume of severe TBIs cared for at the respondents' institutions per year. **C)** Reported frequency of individual neurotrauma physicians providing TBI care. **D)** Years in practice for survey respondents.

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**Fig 2. Responses to survey questions 12, 13, 14, and 15 (S1 Survey, Supplemental Digital Content 1) are presented in A, B, C, and D, respectively.** General surgeons returned a larger number of survey responses (109), neurosurgeons returned 37 responses; the remaining practitioners (neither GS nor NS) returned 7 surveys. **A)** The proportion of respondents that reported awareness of the IMPACT prognostic calculator by specialty. **B)** Reported frequency of use of the IMPACT prognostic calculator in patient management by specialty ( $p = 0.236$ ). Over 45% of all respondents that were aware of the calculator “Never” use it in practice. **C)** Influence of IMPACT prognostic calculations on patient care by specialty. **D)** Reported uses of the IMPACT prognostic calculator by specialty. Respondents could select more than one option.

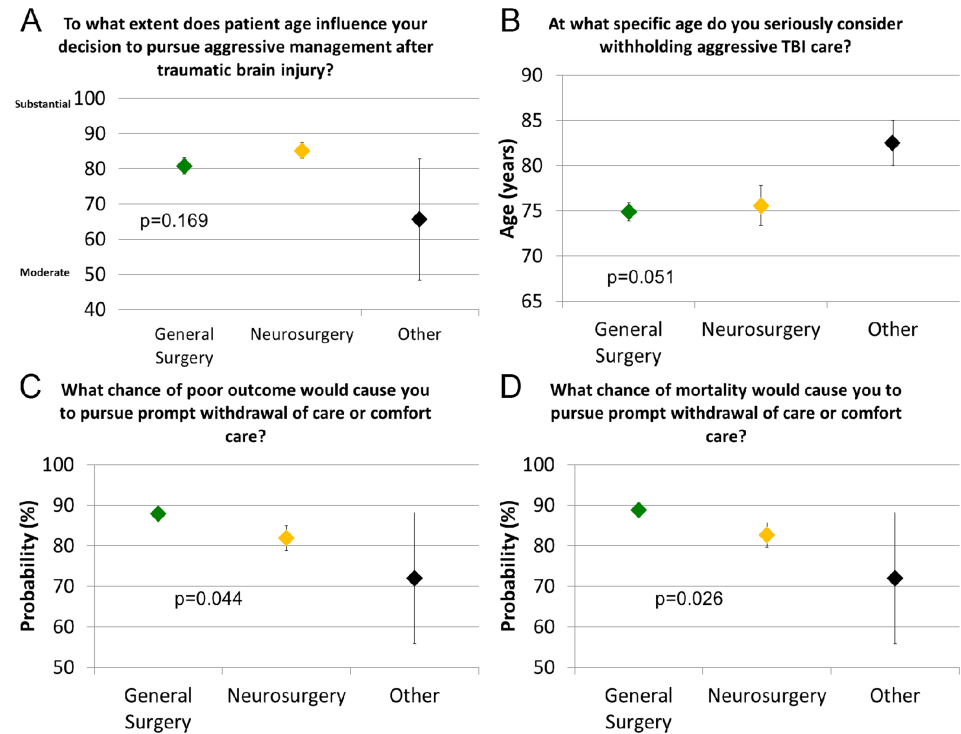
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patient age has a strong influence on their decision. On a scale from 0 to 100 with 0 being no influence of age and 100 being maximal influence of age, neurosurgeons responded 85.0 on average while general surgeons responded 81.6 and other practitioners responded 61.1 ( $p = 0.169$ , Fig 3A). Considering the average response of all who answered the survey, an age of 75.7 years was favored as an age at which nonaggressive care might be strongly considered. Among neurosurgeons, the average age identified was 77.2 years, for general surgeons it was 74.9 years, and among other practitioners it was 83.3 years ( $p = 0.051$ , Fig 3B).

We also sought to determine whether there was a level at which the chance of mortality or poor outcome would prompt practitioners to strongly consider withholding aggressive care. Overall, an 85.9% chance of poor outcome was the average threshold that would prompt the pursuit of comfort care (neurosurgeons 81.4%, general surgeons 87.9%, other practitioners 79.3%) ( $p = 0.044$ , Fig 3C). Similar responses were provided with respect to chance of mortality that would prompt consideration of comfort care. Overall, 86.7% chance of mortality was the average that would prompt the pursuit of comfort care (neurosurgeons 82.2%, general surgeons 88.8%, other practitioners 78.6%) ( $p = 0.026$ , Fig 3D).

### Predictors of physician aggressiveness

To explore factors associated with physician aggressiveness, we chose to use the mortality threshold at which physicians would consider withholding aggressive care as a surrogate measure of aggressiveness. We compared physician demographic values to the threshold value for



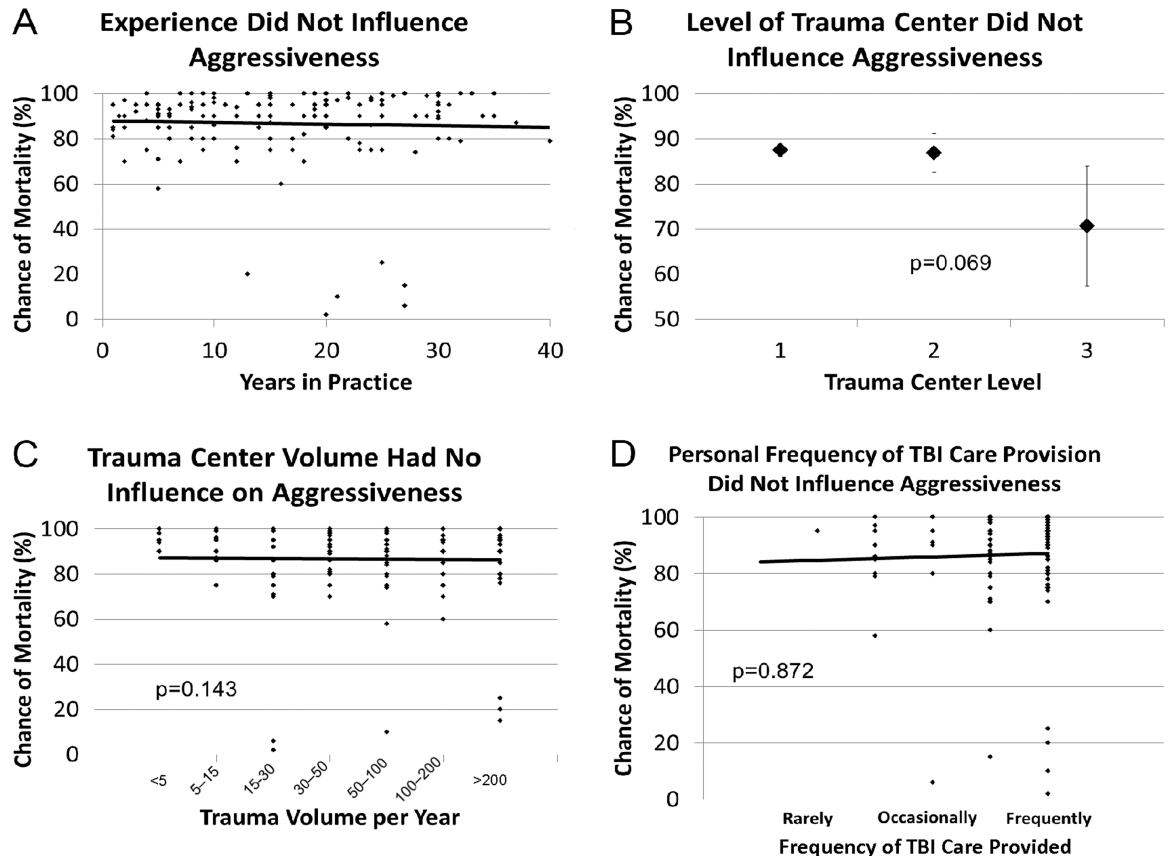
**Fig 3. Responses to survey questions 18, 19, 17, and 16 (S1 Survey, Supplemental Digital Content 1) are presented in A, B, C, and D, respectively.** In our survey, we posed a series of questions that assumed the calculator produced results that were 100% accurate. **A)** Reported extent to which age influences aggressive care among different specialties, by specialty. Just over 10% of all respondents said that age had no influence on their decision making. **B)** Reported age threshold at which one might consider withholding aggressive care, by specialty. **C)** Reported chance of poor outcome that prompts comfort care considerations, by specialty. **D)** Reported chance of mortality that prompts comfort care considerations, by specialty. Error bars represent standard error.

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mortality at which the physician would seriously consider withdrawing care. Years of physician experience did not significantly influence aggressiveness ( $p = 0.148$ , Fig 4A). Similarly, the physician’s trauma center designation, TBI volume, and personal frequency of TBI care did not significantly influence aggressiveness, although respondents at Level III trauma centers indicated they would withdraw care based on lower predicted mortality values than those at higher designated centers ( $p = 0.069$ , Fig 4B).

## Discussion

The development and validation of the IMPACT prognostic model was published in 2008[5]. The results of the univariate and multivariate prognostic analyses were published as a Supplemental Issue in the *Journal of Neurotrauma* in February 2007 [11]. Despite the many important achievements of the IMPACT study approximately a decade since its initial publication, relatively little is known about if and how clinicians are currently using the IMPACT prognostic calculator. It is our belief that the IMPACT prognostic calculator has been a substantial advancement in the care of TBI victims but that it is being insufficiently utilized. The IMPACT prognostic calculator could have particularly important utility in helping to reduce variability and nihilism in decisions surrounding care of the severely brain injured. The first step in achieving this possibility is to understand how providers are currently using the calculator and their views on the aggressiveness of patient care.



**Fig 4. Effect of variables on physician aggressiveness.** **A)** Chance of mortality that prompts withholding aggressive care by years in practice. **B)** Chance of mortality that prompts withholding aggressive care by trauma center level. **C)** Chance of mortality that prompts withholding aggressive care by trauma volume per year. **D)** Chance of mortality that prompts withholding aggressive care by frequency of TBI care provided.

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### Physician aggressiveness in the care of TBI patients

Despite the frequency with which most neurosurgeons make decisions about when to provide aggressive care to severely brain-injured patients, there has been little effort to reduce variability in these decisions or to objectify the notion of nihilism in this population. Although clinical judgement and individual patient characteristics must remain the most important factors in making these decisions, a better understanding of how prognostic calculations are interpreted by physicians may assist these decisions. We believe that there is great value in seeking consensus in what may constitute nihilism and that this may lead to the development of a safeguard against inappropriate therapeutic nihilism.

Neurotrauma physicians face a number of challenges early in the treatment course for brain-injured patients. These include but are not limited to communicating the nature of the insult as well as a sense of the prognosis that is as objective as possible, the time frame for neurological recovery, and the certainty in achieving the predicted functional state [12]. They must also establish a plan of care that reflects input from the family and the views of the medical team. Uncertainty inherent to the outcome that would be achieved with aggressive care adds greatly to the challenge of these tasks. Unfortunately, clinicians' opinions vary greatly when it comes to outcome predictions [6, 13, 14] and tend to fall on the pessimistic side of the spectrum [6]. The IMPACT prognostic calculator can thus serve as an important and objective

aid in the prognostication of moderate and severe TBI, although there has been no previous attempt to do this to our knowledge.

## The IMPACT prognostic calculator

Prediction of outcome after TBI has been a holy grail in medicine. A very large number of published papers describe prognostic variables in the severe TBI population and numerous prediction models have been described over the last century [5, 7, 15–45]. Accurate prediction of outcome in TBI patients can assist with counseling families, aid in determining appropriate resource utilization, and help to prevent undesirable outcomes. Indeed, academic efforts to define prognostic variables in TBI have been going on since at least 1923 [46].

The very large IMPACT database was developed in part to improve prognostic assessment of moderate and severe TBI victims. The IMPACT prognostic calculator is the most mature and studied prognostic calculator currently in use [8, 23, 47–52]. The large number of patients was important in overcoming the heterogeneity of the TBI population [53]. The IMPACT calculator (<http://www.tbi-impact.org/?p=impact/calc>) offers three highly validated [41] prognostic models (Core, Core + CT, and Core + CT + Lab) into which data available early after injury can be input [42]. The IMPACT prognostic calculator has been demonstrated to explain approximately 80% of the variability in patient outcomes, and its use is encouraged by the American College of Surgeons Trauma Quality Improvement Program as a means of scrutinizing the quality of care provided to TBI victims [54].

## Current use of the IMPACT prognostic calculator

Even though the IMPACT prognostic calculator has arguably been one of the most important advances in modern TBI care, the results of our survey suggest that physician awareness of this tool is insufficient among those who provide care to patients with moderate and severe TBI [25, 55]. Greater awareness among neurosurgeons was anticipated because the IMPACT model was predominantly a neurosurgical effort. Greater awareness and use among junior faculty likely reflects exposure to relevant IMPACT literature during training. Even among those that use the calculator, our survey indicates that it currently receives greatest use as a tool to improve communication with families; however, the IMPACT calculator has the potential to serve as a tool for much more.

Time needed to gather the data required to complete the online IMPACT calculation is likely an important factor limiting more extensive use and influence of the IMPACT calculator, especially in the most urgent clinical situations. This may underlie the reported lack of use and influence of the calculator at least to some extent. To address this problem our group has embedded the IMPACT calculator within a widely used medical record software, automating much of the data gathering and shortening the time to perform a calculation. This embedded calculator is a subject of ongoing work and investigation by our group.

## Consensus on when to provide aggressive care

According to the survey responses we received, there seems to be a strong consensus on when it may be reasonable to pursue comfort care. When including all responses, the average chance of mortality as predicted by the IMPACT calculator that would cause prompt pursuit of palliative care was 86.7%. This number was 85.9%—very similar—when participants were asked about chance of poor outcome and pursuit of palliative care. Our data demonstrate a strong consensus among physicians that a high chance of mortality and/or poor outcome is required before withdrawal of aggressive care is considered. Interestingly, the thresholds we identified align with the findings of a 2011 study looking at the cost-effectiveness of decompressive



craniectomy for severe TBI [56], which suggested that the hospital costs associated with this procedure increase as the severity of TBI increases and peak at a predicted risk of unfavorable outcome around 80%.

Our survey also demonstrated robust agreement that aggressive care should be strongly considered in patients younger than an age threshold of 76 years. Age is the strongest predictor of outcome after TBI [57]; remarkably, its prognostic importance exceeds that of the Glasgow Coma Scale motor score. Interestingly, the age threshold identified in our study aligns with a 2012 study published by Whitmore et al. [58] which showed that, when all the costs of severe TBI are considered, aggressive treatment is a cost-effective option compared with “routine care” up to 80 years of age.

## Prognostic thresholds must not be misused

A very important contribution of IMPACT’s high-resolution, “big-data” analysis of the relationship between continuous variables and outcome was to dispel the notion of thresholds in TBI prognostication [59]. A spline function failed to suggest a threshold age at which there is a marked change in outcome, for instance. Thresholds in the TBI field have generally arisen as a result of arbitrary cut-points to dichotomize data for statistical analysis. Nonetheless, the notion of thresholds is entrenched in the care of TBI victims as guidelines recommend treatment thresholds for systolic blood pressure, intracranial pressure, cerebral perfusion pressure, and jugular venous oxygen saturation. This reflects the practicality that values must be identified at which treatment should be initiated to mitigate harm.

We feel strongly that the thresholds identified in our work should not be misused. Moreover, physicians must consider that these are consensus-based thresholds and that the age threshold we have identified is not associated with a marked change in outcome—outcome at the age of 77 is similar to that seen at the age of 75 for instance [59]. All decisions related to aggressiveness of care must be individualized, and the thresholds we have identified should not by themselves constitute reason for pursuing non-aggressive care. Here it is important to consider the misuse of an age threshold discussed in the first prognosis guidelines of the Brain Trauma Foundation, which were paired with the second edition of the Guidelines for the Management of Severe TBI [3]. An age threshold of 65 years was discussed in the Brain Trauma Foundation’s Prognostic Guidelines, and this prompted some to withhold treatment even for healthy individuals older than 65. Decisions restricting aggressive care in older individuals or those with chance of death or poor outcome exceeding 85% should have a strong basis in individual characteristics, family wishes, and physician judgement.

## Limitations

A number of limitations of our work must be considered. Surveys involving voluntary participation such as this may not reflect the opinions of non-respondents and may thus not represent true consensus. It is remarkable, however, that the thresholds identified in our work were consistent amongst key subgroups. It must also be considered that a survey of physician opinions such as this may not accurately reflect real-world behavior. While it would be interesting to compare physician opinion with physician practice such an investigation is beyond the scope of this survey. Comparing such stated opinion with real-world practice is an important subject for future research.

## Conclusions

This study shows that many physicians who provide care to patients with moderate or severe TBI are unaware of the IMPACT prognostic calculator. Of those clinicians that were aware of

the calculator, most use the tool to aid discussion with families, and few reported that the prognostic calculations strongly influence their care of TBI patients. Our multidisciplinary, international survey provides valuable information as to the aggressiveness of physicians, and it identified robust thresholds for predicted poor outcome, mortality, and age which—with further study—may ultimately help to bring greater objectivity to level-of-care decisions for the most severely injured patients.

## Supporting information

**S1 Survey. Physician survey.**  
(PDF)

## Author Contributions

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**Visualization:** Joshua Letsinger.

**Writing – original draft:** Joshua Letsinger, Gregory W. J. Hawryluk.

**Writing – review & editing:** Joshua Letsinger, Casey Rommel, Ryan Hirschi, Raminder Nirula, Gregory W. J. Hawryluk.

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