North American survey on the post-neuroimaging management of children with mild head injuries

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OBJECTIVE There remains uncertainty regarding the appropriate level of care and need for repeating neuroimaging among children with mild traumatic brain injury (mTBI) complicated by intracranial injury (ICI). This study's objective was to investigate physician practice patterns and decision-making processes for these patients in order to identify knowledge gaps and highlight avenues for future investigation.

METHODS The authors surveyed residents, fellows, and attending physicians from the following pediatric specialties: emergency medicine; general surgery; neurosurgery; and critical care. Participants came from 10 institutions in the United States and an email list maintained by the Canadian Neurosurgical Society. The survey asked respondents to indicate management preferences for and experiences with children with mTBI complicated by ICI, focusing on an exemplar clinical vignette of a 7-year-old girl with a Glasgow Coma Scale score of 15 and a 5-mm subdural hematoma without midline shift after a fall down stairs.

RESULTS The response rate was 52% (n = 536). Overall, 326 (61%) respondents indicated they would recommend ICU admission for the child in the vignette. However, only 62 (12%) agreed/strongly agreed that this child was at high risk of neurological decline. Half of respondents (45%; n = 243) indicated they would order a planned follow-up CT (29%; n = 155) or MRI scan (19%; n = 102), though only 64 (12%) agreed/strongly agreed that repeat neuroimaging would influence their management. Common factors that increased the likelihood of ICU admission included presence of a focal neurological deficit (95%; n = 508 endorsed), midline shift (90%; n = 480) or an epidural hematoma (88%; n = 471). However, 42% (n = 225) indicated they would admit all children with mTBI and ICI to the ICU. Notably, 27% (n = 143) of respondents indicated they had seen one or more children with mTBI and intracranial hemorrhage demonstrate a rapid

ABBREVIATIONS ED = emergency department; GCS = Glasgow Coma Scale; ICI = intracranial injury; ICU = intensive care unit; mTBI = mild TBI; OR = odds ratio; TBI = traumatic brain injury.

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neurological decline when admitted to a general ward in the last year, and 13% (n = 71) had witnessed this outcome at least twice in the past year.

CONCLUSIONS Many physicians endorse ICU admission and repeat neuroimaging for pediatric mTBI with ICI, despite uncertainty regarding the clinical utility of those decisions. These results, combined with evidence that existing practice may provide insufficient monitoring to some high-risk children, emphasize the need for validated decision tools to aid the management of these patients.

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KEYWORDS traumatic brain injury; health services research; clinical decision making; survey research; intracranial injury; trauma

HHEAD trauma is a leading public health issue affecting children, causing approximately 600,000 emergency department (ED) visits and up to 60,000 hospitalizations each year in the United States.^{6,34} Healthcare encounters for traumatic brain injury (TBI) are increasing; the rate of ED visits for TBI increased more than 8 times faster than the rate of overall ED visits between 2006–2010.^{10,35} Generally characterized with a presenting Glasgow Coma Scale (GCS) score of 13–15,⁹ mild TBI (mTBI) accounts for more than 90% of new TBI diagnoses and represents an increasingly important subtype of TBI management.^{10,30,35}

Substantial research has been dedicated to identifying which children with mTBI should undergo acute head CT imaging. With the goal of reducing the substantial variations in head CT utilization,^{33,37,41} 3 independent decision tools were developed and validated in multicenter studies; these tools have significantly improved evidence-based guidance regarding mTBI imaging decisions.^{4,13,32,38}

Comparatively less attention has been focused on the post-CT acute management of children with mTBI, including key questions such as the appropriate level of care and role of repeat neuroimaging. These questions have particular salience in the management of children with mTBI complicated by intracranial injury (ICI), where available evidence suggests that admission practices vary across specialties and that level-of-care decisions often fail to correlate with patients' evidence-based risk.^{18,42} While there are emerging evidence-based tools to help guide level-of-care decisions,¹⁸ it remains unclear what considerations currently influence physician decision making in this population. Likewise, there remains ongoing debate and uncertainty regarding the role of and indications for repeat neuroimaging in the management of these patients.^{16,21,23,39}

Survey studies offer an efficient means of describing current practice, identifying knowledge gaps, and highlighting areas requiring further investigation.^{7,31} With these motivations, we conducted a survey to characterize current practice patterns and identify influences on physician decision making in the post-neuroimaging acute care of children with mTBI complicated by ICI.

Methods

Study Participants

This study was approved with exempt status by the Washington University in St. Louis institutional review board (IRB) and was also approved by the IRB at each participating institution that deemed such oversight necessary.

Study participants came from 10 institutions in the

United States and from an email registry maintained by the Canadian Neurosurgical Society (see the *Appendix* for a list of participating institutions). These centers were identified in part by solicitation at a meeting of the Pediatric Neurocritical Care Research Group. Study participants included attending and fellow physicians from the following pediatric disciplines involved in the care of mTBI: emergency medicine, general surgery, neurosurgery, and critical care. Senior (PGY-4 and above) general surgery and neurosurgery residents were also surveyed.

Survey Development

Following standard survey methods,²⁹ we used literature review and input from a team of experts in clinical TBI practice and survey methodologies to develop a 50-item questionnaire to survey physicians about their attitudes and practices in the post-neuroimaging management of pediatric mTBI. Subsequently, we engaged in incremental evaluation and refinement of this preliminary tool, given the importance of pretesting in improving questionnaire quality.¹¹ First, detailed cognitive interviews were conducted with 8 clinical experts in pediatric mTBI who were not part of the research team.^{24,25} During these interviews, clinicians completed and provided feedback on the survey, including explaining what they thought the questions meant and how they arrived at their responses. Participants were paid \$50.

After the survey was revised on the basis of these interviews, a pilot study of the same specialties listed above was conducted at Washington University School of Medicine. Respondents were entered to win one of four \$50 prizes. Out of 134 surveys emailed, 68 were returned. Pilot data were examined to gauge response rates and to identify questions with minimal variability in responses (e.g., nearly all respondents agreed/strongly agreed), which were often dropped. Based on multidisciplinary review of the pilot data, a final survey was developed. The survey development is detailed in Fig. 1.

Measures

The survey was divided into 7 sections and took about 10 minutes to complete. Each of the first 3 sections focused on one of 3 clinical vignettes based in the ED. Respondents were asked to characterize the child's injury and offer their professional opinions related to the appropriate acute management (e.g., next level of care and need for repeat neuroimaging). Multiple-choice or 5-point Likert-type scaled response options ranging from "strongly disagree" (1 point) to "strongly agree" (5 points) were used. For this report, we

FIG. 1. Schematic depiction of the survey development process.

focused on the vignette involving a 7-year-old girl with a GCS score of 15 and a 5-mm subdural hematoma without midline shift after a fall down the stairs. This vignette was designed to illustrate a patient who available decision aids suggest is at low risk of neurological decline and therefore may not necessarily require ICU admission or planned repeat neuroimaging.^{1,8,17,18} The full vignette is provided in the Online Appendix. The 2 other vignettes involved children without ICI and will be described in a forthcoming manuscript focused on that patient population.

The fourth section (*Influences on Decision Making*) asked respondents to select the clinical and radiological factors that influenced their decisions about the appropriate level of care for children with mTBI. In addition, respondents used a 5-point Likert-type scale (ranging from “never” [1] to “always” [5]) to rate the frequency that other factors (e.g., one’s “gestalt impression” and standard institutional practice) influenced their decision making. The fifth section (*Recent Experiences with TBI Patients*) asked respondents about their experiences observing mTBI (GCS score 13–15) patients undergoing unexpected neurological decline or radiological progression during the last year. The sixth section (*Shared Decision Making [SDM]*) used a previously developed guide to ask respondents how frequently various factors (e.g., medicolegal concerns) served as barriers to utilizing SDM in the post-neuroimaging management of pediatric mTBI patients.²⁸ The results from this section will be reported with the upcoming manuscript on the management of children without ICI. The final section (*Demographics*) included questions asking about respondents’ characteristics and practice settings.

Survey Administration

Site principal investigators at each institution collected and shared email addresses of potential eligible participants with the data coordination site at Washington University

in St. Louis. The voluntary survey was then administered via unique emails sent using the Qualtrics server from August 3, 2016, to January 30, 2017. Surveys were completed anonymously. After the initial distribution, 4 follow-up emails were sent approximately 1 week apart to potential participants. Participants were offered \$10 compensation.

Statistical Analysis

We analyzed surveys that had at least 50% of the survey items completed and treated the remaining surveys as nonresponses.² Descriptive statistics were reported for all items. The primary outcome was the level of care recommended for the child with mTBI complicated by ICI in the vignette. The secondary outcome was the decision to order planned repeat neuroimaging for this child before hospital discharge. This outcome was defined as endorsing “agree” or “strongly agree” with ordering a repeat CT or MRI scan for the child.

After conducting univariate logistic regression analyses, variables with p values < 0.2 for each outcome were entered into a multivariable logistic regression model using backward selection, and variables with $p < 0.05$ in this multivariable analysis were retained. Complete case analysis was used, given the small amount of missing data. For respondent specialty, missing data were grouped in the “other” category. Respondents “not sure” if their institution was a Level 1 trauma center were grouped in the “no” category.

For increased statistical power, we treated items with Likert-type scaled responses as continuous numerical variables and reported the mean and standard deviation for each item. In cases where the linearity of continuous predictors with the outcome was questionable, we ensured that the final model did not change with these variables recategorized into 3 groups: strongly disagree/disagree, neutral, and agree/strongly agree (data not shown). Statisti-

cal analyses were conducted using SAS version 9.4 (SAS Institute Inc.).

Results

A total of 1022 email surveys were distributed, and 536 respondents completed at least 50% of the survey items, yielding a 52% response rate. The discipline with the largest group of respondents was emergency medicine (38% of the overall group), followed by critical care (25%), neurosurgery (21%), and general surgery (13%). Most respondents (63%) were attendings, were male (52%), and worked at freestanding children's hospitals (76%). Only 5% of respondents practiced in Canada. Demographic information is shown in Table 1.

Respondents varied their responses regarding the appropriate terminology to characterize the injury in the vignette, which involved a 7-year-old girl with a GCS 15 head injury and a "5-mm subdural hematoma without midline shift or signs of herniation." Most respondents (59%) endorsed the term "GCS 13–15 head injury with ICI," while the remainder were split among the terms mild (13%), complicated mild (26%), moderate (28%), and severe (3%) TBI.

Responses to the vignette are listed in Table 2. Overall, 326 (61%) respondents indicated that they would recommend ICU admission for the child in the vignette, though only 62 (12%) agreed/strongly agreed that this child was at high risk of neurological decline, with about one-third of respondents (36%; $n = 191$) being neutral. The majority (77%, $n = 412$) agreed/strongly agreed with involving family in their level-of-care decision. Slightly fewer than half of the respondents (45%; $n = 243$) indicated they would order a planned follow-up CT (29%; $n = 155$) or MRI (19%; $n = 102$) before hospital discharge, though only 64 (12%) agreed/strongly agreed that repeat neuroimaging would likely influence their clinical management. Planned repeat neuroimaging was most frequent among neurosurgeons (68%) and other unlisted specialties (68%), and less frequent among critical care physicians (49%), general surgeons (43%), and emergency physicians (29%).

Beyond this specific vignette, the clinical and radiological factors that generally influenced respondents' decisions to admit children with mTBI complicated by ICI to the ICU are listed in Table 3. The most common factors influencing admission decisions included presence of a focal neurological deficit (95%), midline shift on CT (90%), and presence of an epidural hematoma (88%), with subdural hematoma (54%) and posttraumatic seizure (53%) being other common responses. Notably, 42% of respondents indicated that they would admit all children with ICI to the ICU, regardless of the specific clinical or radiological findings. Among other influences on decision making, understanding of the medical literature (74% always/often utilized) and gestalt impression (69% always/often utilized) had the greatest impact (Online Appendix Table 1).

When asked about their experiences with TBI patients in the past 12 months, 27% indicated that they had seen one or more "clinically stable children with GCS 13–15 closed head injury and intracranial hemorrhage, experience a rapid neurological decline when admitted to a gen-

eral ward" in the last year, and 13% had witnessed this outcome at least twice in the past year (Online Appendix Table 2). In addition, 35% indicated that they had recently seen clinically stable children with GCS 13–15 closed head injury and intracranial hemorrhage require neurosurgical intervention for an enlarging hematoma seen on repeat imaging in the absence of any neurological decline.

Variables Associated With Level-of-Care Decisions

In univariate analysis, we found a number of factors associated with the level-of-care decision in the vignette. These included demographic factors (e.g., specialty, training level); feelings about the importance of involving family; beliefs about the child's likely clinical course and the role of repeat neuroimaging; importance placed on understanding of the medical literature, gestalt impression, and malpractice liability; and recent experiences with TBI patients (Tables 1 and 2; Online Appendix Tables 1 and 2).

The multivariable model is shown in Table 4. In this analysis, critical care physicians (OR 2.2), general surgeons (OR 2.7), and neurosurgeons (OR 1.9) were at least twice as likely as emergency medicine physicians to recommend ICU admission. Physicians not working at a freestanding children's hospital were also twice as likely to recommend ICU admission (OR 1.8). In addition, providers who believed that the child was at risk of neurological decline (OR 1.6), those who relied on their "gestalt impression" (OR 1.4), and those who would obtain a repeat CT (OR 1.3) or MRI (OR 1.3) were more likely to recommend ICU admission.

Variables Associated With Repeat Neuroimaging Decisions

In univariate analysis, we found a number of factors significantly associated with the decision to order repeat neuroimaging in the vignette. These included demographic factors (e.g., provider specialty and age), beliefs about the child's clinical course, and recent experiences with TBI patients. The complete univariate results are shown in Online Appendix Table 3.

The multivariable model of factors associated with planned repeat neuroimaging is shown in Table 5. In this analysis, physicians who favored ICU admission, those who believed repeat imaging was likely to influence their management, and respondents from neurosurgery and "other" unlisted specialties were more likely to order repeat imaging. Physicians from freestanding children's hospitals were less likely to order repeat imaging. Repeat imaging behavior also varied with age and training level, with repeat neuroimaging being more common among respondents older than 50 than among those younger than 40 years and less frequent among attendings than among residents.

Discussion

Although evidence-based indications for head CT imaging in pediatric mTBI have been established, there is a paucity of literature providing evidence for the routine post-neuroimaging management of these patients, including key topics such as the appropriate level of care and need for repeat neuroimaging.^{1,8,18,21,22} Understanding clinicians'

TABLE 1. Demographic characteristics of survey respondents

Characteristic	All (%), n = 536	Admit to Floor (%), n = 208	Admit to ICU (%), n = 326	p Value*
Specialty				
Emergency medicine	205 (38.3)	109 (52.4)	96 (29.5)	Ref
Critical care	132 (24.6)	41 (19.7)	91 (27.9)	<0.01
General surgery	68 (12.7)	19 (9.1)	49 (15.0)	<0.01
Neurosurgery	112 (20.9)	30 (14.4)	80 (24.5)	<0.01
Other	19 (3.5)	9 (4.3)	10 (3.1)	0.63
Training level				
Resident	91 (17.4)	19 (9.3)	72 (22.7)	Ref
Fellow	101 (19.3)	41 (20.1)	60 (18.9)	<0.01
Attending	331 (63.3)	144 (70.6)	185 (58.4)	<0.01
Age				
<40	304 (58.1)	118 (57.8)	186 (58.7)	Ref
40–49	135 (25.8)	59 (28.9)	75 (23.7)	0.31
≥50	84 (16.1)	27 (13.2)	56 (17.7)	0.30
Sex				
Female	247 (47.7)	107 (52.7)	140 (44.7)	0.08
Male	271 (52.3)	96 (47.3)	173 (55.3)	Ref
No. of children w/ mTBI cared for per yr				
0–20	135 (25.9)	41 (20.2)	94 (29.7)	<0.01
20–39	155 (29.7)	57 (28.1)	96 (30.3)	0.12
≥40	232 (44.4)	105 (51.7)	127 (40.1)	Ref
Level 1 trauma center†				
Yes	494 (94.3)	193 (94.6)	299 (94.0)	Ref
No	30 (5.7)	11 (5.4)	19 (6.0)	0.78
Academic medical center‡				
Yes	499 (95.2)	197 (96.6)	300 (94.3)	Ref
No	25 (4.8)	7 (3.4)	18 (5.7)	0.25
Independent children's hospital				
Yes	400 (76.3)	169 (82.8)	230 (72.3)	Ref
No	124 (23.7)	35 (17.2)	88 (27.7)	<0.01
Hospital location				
Urban	487 (93.1)	186 (91.2)	299 (94.3)	Ref
Non-urban	36 (6.9)	18 (8.8)	18 (5.7)	0.17
Hospital region				
Canada	27 (5.3)	13 (6.4)	13 (4.2)	Ref
Northeast	55 (10.7)	22 (10.8)	33 (10.7)	0.40
South	204 (39.7)	74 (36.5)	129 (41.8)	0.18
Midwest	31 (6.0)	10 (4.9)	21 (6.8)	0.18
West	197 (38.3)	84 (41.4)	113 (36.6)	0.48

Data are numbers of respondents (%). Percentage values reflect each level's proportion of the total number of respondents within a given column (floor vs ICU). Discrepancies in column totals reflect a small amount of missing data for ICU admission (n = 2), training level (n = 13), age (n = 13), sex (n = 18), number mTBI children cared for (n = 14), Level 1 trauma center (n = 12), academic medical center (n = 12), independent children's hospital (n = 12), hospital location (n = 13), and hospital region (n = 22).

* Based on univariate logistic regression predicting the level-of-care decision (floor vs ICU) for the child in the clinical vignette.

† "Not sure" counted as "not level 1."

‡ "Not sure" counted as "no."

underlying cognitive processes is an essential component of evaluating management decisions and designing clinical decision aids to support evidence-based practices.^{15,27} Nonetheless, there are limited data describing provider

practices and preferences in this domain. This study, based on a multicenter, multidisciplinary survey, was undertaken to fill that void. We found that most physicians would admit a neurologically intact child with a small subdural

TABLE 2. Respondents' opinions and management preferences regarding the clinical vignette involving a 7-year-old girl with a GCS score of 15 and a 5-mm subdural hematoma after a fall down the stairs

	All	Admit to Floor	Admit to ICU	p Value*
Appropriate consults, n (%)				NA
Critical care	124 (23.1)	5 (2.4)	119 (36.5)	
General surgery	327 (61.0)	100 (48.1)	227 (69.6)	
Neurosurgery	532 (99.3)	205 (98.6)	325 (99.7)	
Pediatrics	15 (2.8)	8 (3.9)	7 (2.2)	
Other	2 (0.37)	1 (0.48)	1 (0.31)	
No consult indicated	1 (0.19)	0 (0)	1 (0.31)	
How would you characterize the injury, n (%)				NA
Mild TBI	69 (12.9)	30 (14.4)	39 (12.0)	
Complicated mild TBI	138 (25.8)	59 (28.4)	79 (24.4)	
GCS 13–15 head injury w/ intracranial injury	317 (59.4)	127 (61.1)	189 (58.3)	
Moderate TBI	150 (28.1)	56 (26.9)	93 (28.7)	
Severe TBI	17 (3.2)	1 (0.48)	16 (4.0)	
Important to involve family in my decision regarding the appropriate level of care, mean (SD)	3.98 (1.03)	4.11 (0.94)	3.90 (1.08)	0.02
This child is likely to undergo neurological decline, mean (SD)	2.56 (0.80)	2.31 (0.69)	2.71 (0.83)	<0.01
I am confident in my assessment of the risk of neurological decline, mean (SD)	3.85 (0.70)	3.82 (0.71)	3.88 (0.69)	0.33
Before discharge I would order a repeat CT scan, mean (SD)	2.59 (1.23)	2.27 (1.04)	2.79 (1.30)	<0.01
Before discharge I would order a follow-up MRI scan, mean (SD)	2.41 (1.10)	2.17 (0.97)	2.56 (1.16)	<0.01
Before discharge I would order repeat CT and/or MRI (strongly agree/agree), n (%)	243 (45.4)	55 (26.4)	187 (57.5)	<0.01
Repeat neuroimaging is likely to influence my clinical management, mean (SD)	2.36 (0.89)	2.14 (0.75)	2.49 (0.94)	<0.01
Within 2 weeks of discharge, this child should have a follow-up appointment with, n (%)				NA
A neurosurgeon	478 (89.2)	185 (88.9)	291 (89.3)	
A trauma surgeon	22 (4.1)	6 (2.9)	16 (4.9)	
Her primary care physician	364 (67.9)	136 (65.4)	228 (69.9)	
A neurologist	52 (9.7)	9 (4.3)	43 (13.2)	
Other	43 (8.0)	10 (4.8)	33 (10.1)	

NA = not applicable (variable not tested as a potentially clinically informative predictor).

Responses either involved selecting all appropriate choices or a Likert-like scale ranging from strongly disagree (1 point) to strongly agree (5 points). Discrepancies in column totals reflect the small amount of missing data for injury characterization (n = 2), need for repeat CT (n = 3), need for follow-up MRI (n = 4), and influence of repeat neuroimaging (n = 1).

* Based on univariate logistic regression predicting the level-of-care decision (floor vs ICU) for the child in the clinical vignette.

hematoma to the ICU and nearly half would order routine repeat neuroimaging, despite low concern regarding this child's risk of neurological decline and low expectations regarding the utility of a follow-up scan. These practices varied across specialty and practice settings and appeared influenced by a number of provider beliefs, motivating and informing future studies of the appropriate level of care and need for repeat neuroimaging in this population.

With respect to children with mTBI and ICI who do not require upfront surgical intervention, one of the key decisions facing providers relates to the level of care required. In the vignette presented, we described a neurologically intact child with mTBI complicated by a small subdural hematoma, the most common type of ICI encountered in this population.¹⁸ To our knowledge, all studies of this population characterize the child in this vignette as being at low risk of neurological decline and recommend against ICU admission;^{1,8,17,18} yet 61% of respondents recommended ICU admission and 42% indicated they would recommend ICU admission for all children with ICI, though only

12% thought that this child was at high risk for neurological decline. These results highlight the wide variations and potentially avoidable resource utilization associated with current practices.

Beyond promoting potentially unnecessary ICU admissions, the variations in current practice may also place some patients at risk of significant harm. Supporting this notion, more than 25% of survey respondents reported that they had seen children with mTBI complicated by ICI experience neurological decline on a general ward in the last year. This result builds on existing evidence suggesting that current practice based on clinical gestalt not only sends many low-risk children to the ICU, it also provides insufficient attention to the minority of patients truly at increased risk of neurological decline.¹⁸ These findings emphasize the need for rigorously validated decision tools to support evidence-based level-of-care decisions.

The secondary outcome in this study focused on the need for routine repeat neuroimaging following mTBI complicated by ICI, a source of ongoing debate and in-

TABLE 3. Clinical and radiologic influences indicating the need for ICU observation for children with GCS 13–15 head injuries and intracranial injury

	No. (%) Agreeing
I would admit all children with GCS 13–15 head injuries and ICI to the ICU	225 (42.1)
Post-traumatic seizure	282 (52.9)
Severe mechanism of injury	325 (61.0)
Midline shift (<5 mm)	480 (90.1)
Depressed skull fracture (depressed at least the width of the skull)	322 (60.4)
Epidural hematoma (no midline shift)	471 (88.4)
Subdural hematoma (no midline shift)	289 (54.2)
Subarachnoid hemorrhage (no midline shift or ventriculomegaly)	235 (44.1)
Cerebral contusion (no midline shift)	223 (41.8)
Intraventricular hemorrhage (no midline shift or ventriculomegaly)	336 (63.0)
GCS score 14	98 (18.4)
GCS score 13	300 (56.3)
Presence of a focal neurological deficit	508 (95.3)
Patient age <2 yrs	331 (62.1)
Other	34 (6.4)

Respondents were asked to select as many options as they agreed with (yes/no option). There were 3 missing responses.

vestigation. Although several authors have suggested that repeat neuroimaging studies may be low yield,^{3,12,39} other studies have reported high rates of radiological progression.¹⁶ Given that nearly half of respondents supported ordering repeat neuroimaging but only 12% thought it was likely to change clinical management, higher-level multicenter evidence is needed to guide this important decision. In order to obtain this evidence, studies should evaluate not only rates of radiological progression but also the frequency with which such information influences clinical management. Such data, combined with consideration of the impact of ionizing radiation, may inform the development of evidence-based recommendations regarding the role of routine repeat CT or MRI.⁵

Successful uptake of level-of-care and repeat neuroimaging decision aids will depend on rigorous dissemination and implementation strategies,¹⁹ which may be informed by the self-reported variations related to practice setting and provider beliefs revealed in this study. For example, the increased tendency toward ICU admission among those not at freestanding children's hospitals highlights the role of institutional resources and experience, which should be considered in designing broadly generalizable implementation efforts. Likewise, we found that neurosurgeons were significantly more likely than other specialists to order planned repeat neuroimaging for the child in the vignette. Given the key role that neurosurgeons have in this decision-making process, future implementation studies should focus on studying the acceptability and usability of imaging decision aids in this population.

This study has several strengths, including rigorous sur-

TABLE 4. Results of the multivariable analysis predicting the level of care recommended for the child in the clinical vignette

	OR (95% CI)
Specialty	
Emergency medicine	Ref
Critical care	2.2 (1.3–3.6)
General surgery	2.7 (1.4–5.0)
Neurosurgery	1.9 (1.1–3.3)
Other	0.32 (0.07–1.5)
Working at a freestanding children's hospital	
Yes	Ref
No	1.8 (1.1–3.0)
Perceived likeliness of neurological decline	1.6 (1.2–2.1)
Agreement with ordering a repeat CT scan	1.3 (1.1–1.5)
Agreement with ordering a follow-up MRI scan	1.3 (1.1–1.6)
Use of gestalt impression in decision making	1.4 (1.1–1.8)

Odds ratios greater than 1 indicate increased likelihood of recommending ICU admission.

vey development methods, a large sample size, and a multidisciplinary and multicenter respondent base. Nonetheless, it also has limitations. First, our response rate (52%), while good, was still below the standard of 60% set by some authorities.²⁶ However, survey response rates have decreased

TABLE 5. Results of the multivariable analysis identifying factors associated with repeat neuroimaging decisions for the child in the clinical vignette

	OR (95% CI)
Would admit the child in the clinical vignette to the ICU	2.9 (1.8–4.6)
Agreement that repeat neuroimaging is likely to change clinical management	4.3 (3.1–6.1)
Specialty	
Emergency medicine	Ref
Critical care	1.8 (1.02–3.2)
General surgery	1.4 (0.70–3.0)
Neurosurgery	3.4 (1.7–6.8)
Other	8.2 (1.5–44.8)
Training level	
Resident	Ref
Fellow	1.3 (0.57–2.9)
Attending	0.42 (0.18–0.97)
Age in yrs	
<40	Ref
40–49	1.7 (0.85–3.4)
≥50	4.6 (2.2–9.8)
Working at a freestanding children's hospital	
Yes	Ref
No	1.8 (1.0–3.1)

Odds ratios greater than 1 indicate increased likelihood of recommending repeat neuroimaging.

in recent years,⁴⁰ and the association between a lower response rate and nonresponse bias is unclear.^{14,20} Second, to shorten the survey's completion time, we included only 1 exemplar case of a patient with ICI. While this limited the breadth of situations tested, it allowed for more detailed assessment of provider attitudes and influences on decision making. Third, the survey respondents were concentrated at academic tertiary or quaternary institutions and also at freestanding children's hospitals. Consequently, the results may not generalize to community settings or to children treated within a predominately adult institution, which may have different practices and availability of subspecialty care. Finally, this survey focused on physicians and did not investigate the perspectives of midlevel providers, who are assuming a growing role in delivering emergency pediatric care.³⁶

Conclusions

This multicenter multidisciplinary survey indicated that there is wide variation in physician decisions related to the level of care and need for repeat neuroimaging for children with mTBI and ICI. The practices reported are associated with potentially avoidable resource utilization as well as possible patient harm. These observations, along with providers' uncertainty regarding the clinical utility of their recommendations, highlight the need for continued efforts to advance evidence-based decision aids. Once developed and validated, such evidence-based approaches may form the foundation for consensus guidelines to direct the safe, resource-efficient management of these patients.

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Appendix

Participating Centers

Barrow Neurological Institute/Phoenix Children's Hospital; Johns Hopkins Medical Center; Oregon Health and Science University/Doernbecher Children's Hospital; Texas Children's Hospital; University of Colorado/Children's Hospital Colorado; University of Pittsburgh/Children's Hospital of Pittsburgh; University of Tennessee Health Science Center/Le Bonheur Children's Hospital; University of Texas at Houston/Children's Memorial Hermann Hospital; University of Utah/Primary Children's Hospital; and Vanderbilt University/Monroe Carell Jr. Children's Hospital. At the Johns Hopkins School of Medicine, pediatric surgery and pediatric critical care did not share email addresses and were therefore excluded.

Canadian neurosurgeons were also surveyed from a list maintained by the Canadian Neurosurgical Society.

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Supplemental Information

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