Original Contribution

Is repeat head CT necessary in patients with mild traumatic intracranial hemorrhage ☆

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A B S T R A C T

Background: Patients with traumatic intracranial hemorrhage (TIH) frequently receive repeat head CT scans (RHCT) to assess for progression of TIH. The utility of this practice has been brought into question, with some studies suggesting that in the absence of progressive neurologic symptoms, the RHCT does not lead to clinical interventions.
Methods: This was a retrospective review of consecutive patients with CT-documented TIH and GCS ≥ 13 presenting to an academic emergency department from 2009 to 2013. Demographic, historical, and physical exam variables, number of CT scans during admission were collected with primary outcomes of: neurological decline, worsening findings on repeat CT scan, and the need for neurosurgical intervention.
Results: Of these 1126 patients with mild traumatic intracranial hemorrhage, 975 had RHCT. Of these, 54 (5.5% (4.2–7.2 95 CI) had neurological decline, 73 (7.5% 5.9–9.3 95 CI) had hemorrhage progression on repeat CT scan, and 58 (5.9% 4.5–7.6 95 CI) required neurosurgical intervention. Only 3 patients (0.3% 0.1–0.9% 95 CI) underwent neurosurgical intervention due to hemorrhage progression on repeat CT scan without neurological decline. In this scenario, the number of RHCT scans needed to be performed to identify this one patient is 305.
Conclusions: RHCT after initial findings of TIH and GCS ≥ 13 leading to a change to operative management in the absence of neurologic progression is a rare event. A protocol that includes selective RHCT including larger subdural hematomas or patients with coagulopathy (vitamin K inhibitors and anti-platelet agents) may be a topic for further study.

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1. Introduction

Over 1.7 million people in the United States sustain traumatic brain injury (TBI) each year. Head injury encompasses a wide spectrum of clinical symptoms including coma and mild scalp contusions. Patients with a Glasgow Coma Scale (GCS) ≥ 13 are categorized as having a mild traumatic brain injury (mTBI) [1]. A subset of these patients will have findings of intracranial hemorrhage (ICH) on CT imaging and are labelled as having mild traumatic intracranial hemorrhage (mTIH) [2].

Patients with mTIH frequently undergo an observation period for neurologic deterioration and repeat head CT (RHCT), although the vast majority of these patients are managed non-operatively [3,4]. Early head CT ordering and the use of RHCT has been based on experiences

reported in the initial National Coma Data Bank on observed patients who suffered a significant neurologic decline due to an expanding hematoma ("talk and deteriorate") [5]. Even with surgical intervention, such patients experienced significant disability and poor long term outcomes. After these reports and others [6,7], clinical decision rules [8,9] were developed to better define who needed immediate scanning. The practice of repeat scanning has been appealing to clinicians to detect expanding hematoma before clinical decline yet had not been formally studies until recently. Further arguments for RHCT include documentation of hemorrhage stability to aid in triage of patients (ICU versus hospital floor), as well as duration of ICU stay [10-13].

However, more recent data regarding the effect of RHCT on patient management has been nebulous as a meta-analysis of 30 studies demonstrated that a RHCT prompted neurosurgical intervention in as few as 0% to as many as 54% of admitted patients [14]. Furthermore, its value in lower risk patients has come into question as mounting research also suggests it can be avoided in those who do not exhibit neurological decline [3,4,15].

Since the RHCT is still used widely as an aid for clinical decision making in patients with TIH [3], this study was designed to investigate the

value of the RHCT in this lower risk population. The objective of this study was to determine how frequently RHCT is performed at a single center and how often it leads to a neurosurgical intervention, especially interventions that occur in the absence of other clinical indications.

2. Methods

2.1. Study design

Retrospective cohort study of 1126 consecutive patients with mild traumatic intracranial hemorrhage (GCS 13–15) who presented to an urban level 1 trauma center from January 1, 2009 to December 31, 2013. Patients were identified by running a query of a proprietary electronic medical record using the International Statistical Classification of Diseases and Related Health Problems (ninth edition) codes for traumatic intracranial hemorrhage (852.00–853.10, 851.00–851.90, 800.00–801.9, 803.00–804.9). Patients with age <16 or GCS <13 as well as those with penetrating head trauma were excluded. All patients had a documented intracranial hemorrhage on initial head CT. If a patient was seen initially and transferred, then the first CT performed at the transferring institution was considered the first CT scan. A positive scan included any of the following hemorrhagic lesions: subdural hematoma, subarachnoid hemorrhage, epidural hematoma or cerebral contusion/intraparenchymal hemorrhage. This study included patients whose imaging revealed multiple types of intracranial lesions as well as patients on anticoagulants or antiplatelet drugs.

All patients had a neurosurgical consultation. Patients with a GCS 15 and small ICH are admitted to the ED observation unit (EDOU) based on a hospital protocol [16]. Those patients with larger ICH (i.e. SDH > 10 mm) and coagulopathies are admitted on a rotating schedule to the trauma surgery, neurosurgery, and neurology services. Additionally, some patients with low-risk, isolated TIH and normalized coagulation profiles could be placed in the ED observation unit at the discretion of the neurosurgical or ED attending physician. RHCTs were ordered at the recommendation of the on-call neurosurgery service, routinely at 6 h and again at the discretion of the treatment team. All CT scans were reviewed by attending radiologists who were on call at the time of the scan. Some initial CT scans were performed at outside facilities and were then interpreted by the on-call radiologist.

The institutional review board at our institution approved this study. This study was designed in accordance with the best practices most recently described by Kaji et al. [17]; data reporting was guided by the STROBE statement [18].

2.2. Outcomes

The primary outcome of this study was the frequency of routine repeat head CT scan. Secondary outcomes were incidence of neurological decline, worsening CT scan, and neurosurgical intervention along with the number of CT scans performed per patient and the time between CT scans. Neurological decline was defined as decreasing mental status, worsening neurologic examination or death. Patients with inoperable injuries who were transitioned to comfort measures were included in the neurological decline group. CT scans were considered to have worsened if new lesions were noted, previously noted lesions increased in size, if there was new midline shift, or midline shift increased compared with the prior scan. Neurosurgical intervention was defined as placement of an intracranial pressure monitor or operative management. Patients who required burr-hole drainage for subacute or acute-on-chronic subdural hematoma (SDH) were included in the neurosurgical intervention group, although these procedures were frequently performed on an elective basis.

2.3. Data collection

A database and standardized data abstraction forms were created using Microsoft Access (Microsoft Corporation, Redmond, WA). After

an initial database query, inclusion and exclusion criteria were applied to the study population. Two emergency medicine physician abstractors who were blinded to the study hypothesis abstracted the data. Abstractors were trained by a senior investigator at the beginning of the abstraction process. Abstractor output was reviewed after the first 100 charts, and again at intervals throughout the review process. CT scan reports were abstracted separately from clinical data to ensure that clinical information did not influence the coding. CT reports were coded separately and then compared on several key variables (thickness of SDH, amount of midline shift if any, presence of mass effect, presence of herniation) to determine if they had worsened.

Patient variables collected included clinical data such as age, gender, daily anti-platelet use (aspirin, clopidogrel), daily anti-coagulant use (warfarin, enoxaparin, novel anticoagulants), and mechanism of injury, which were abstracted from emergency medicine and neurosurgery documentation. Initial GCS, neurologic exam, and neurosurgical recommendations, including disposition, prescribed frequency of neurologic examination, reversal of anti-platelet or anti-coagulants, time to follow-up CT scan, the use of medication to lower intracranial pressure (e.g. mannitol, hypertonic saline) and the need for neurosurgical intervention were obtained from neurosurgical reports and discharge summaries. Initial CT results, repeat CT results, and the time of follow up CTs were extracted from finalized radiology reports. Patients who were transferred from an outside hospital had initial CT images uploaded and interpreted by the study hospital radiologists.

There was no missing data for any of the primary or secondary clinical outcomes. Follow-up information was not collected after hospital discharge Inter-rater reliability was assessed and kappa statistics were calculated for key variables.

2.4. Statistical analysis

Demographic variables were tallied. Patients undergoing RHCT were compared to those who did not. Patients with RHCT and a composite outcome of CT progression, change in neurologic status need for neurosurgery, death/comfort measures only were compared to the set of patients who had none of these outcomes. A multivariate logistic regression model (stepwise, forward model), number needed to treat and confidence intervals were all calculated using SPSS version 21 (IBM Corp, Armonk NY).

3. Results

Of the 1126 patients with traumatic intracranial hemorrhage and GCS ≥ 13, 975 patients received a RHCT as part of their management. In the other 151 patients, the primary team (trauma surgery, emergency medicine, neurology, and/or neurosurgery) judged the patients as stable enough to forego a RHCT. Table 1 compares patients who underwent RHCT with those who received only a single scan. Patient who had multiple RHCT were older and more likely to be on antiplatelet or anticoagulant medications. Regarding our main outcome variables, kappa values were 1.0 for need for neurosurgical intervention and 0.84 for neurologic deterioration variables since we defined specific events and 0.88 for radiographic worsening. A univariate analysis of clinical variables that are associated with a composite outcome of CT progression, change in neurologic status, need for neurosurgery or death/CMO when compared to patients who had none of these outcomes us displayed in Table 2. Multivariate logistic regression analysis identified the following high risk variables associated with our composite outcome: GCS 13 (OR 4.5, 95 CI 2.5–8.2), age ≥ 60 (OR 1.6, 95 CI 1.1–2.3) and SAH (OR 0.25, 95 CI 0.13–0.47). Note that the SAH OR of 0.25 indicates that it was associated with the absence of CT progression, neurologic deterioration or need for neurosurgical procedure. More details regarding how our outcome variables were coded can be seen in Table 3.

The Venn diagram in Fig. 1 illustrates the results of this project. Forty patients (5%, 95 CI 3.7–6.6) underwent a neurosurgical intervention due

Table 1

Characterization of study population and comparison of patients who had RHCT and those managed without RHCT.

Variable	Patients with RHCT n = 975	Patients without RHCT n = 151	OR	95% CI
	Number (%)	Number (%)		
Age (mean, years)	60.5	49.1	p < .001[b]	
Hospital length of stay (days)	4.4	2.2	p < .0001[b]	
Sex (M)	571 (58.56)	94 (62.25)	1.2	0.8–1.7
Past medical history				
Alcohol or drug use	152 (15.59)	20 (13.25)	1.2	0.73–2.0
Hypertension	384 (39.38)	34 (22.52)	2.2	1.5–3.3
Aspirin use	323 (33.13)	21 (13.91)	3.1	1.9–5.0
Warfarin use	115 (11.79)	1 (0.66)	20.1	2.4–144.7
Clopidogrel/other antiplatelet	48 (4.92)	0 (0.00)	0.005[a]	
Mechanism of injury				
Fall	691 (70.87)	85 (56.29)	1.89	1.3–2.7
Assault	105 (10.77)	25 (16.56)	0.6	0.38–0.98
Motor vehicle collision	57 (5.85)	19 (12.58)	0.43	0.25–0.75
PedStruck	48 (4.92)	11 (7.28)	0.66	0.33–1.3
Motorcycle collision	23 (2.36)	4 (2.65)	0.89	0.3–2.6
Bicycle accident	34 (3.49)	7 (4.64)	0.74	0.32–1.7
Glasgow Coma Score				
15	807 (82.77)	134 (88.74)	0.6	0.36–1.04
14	118 (12.10)	12 (7.95)	1.6	0.86–3.0
13	50 (5.13)	5 (3.31)	1.6	0.6–4.0
CT Lesions (combined, totals not percentage				
EDH	54	5		
SDH	584	50		
SAH	481	73		
Contusion	274	28		
Skull fracture	176	36		
CT Lesions (isolated, percentages)				
EDH	4 (0.69)	2 (1.69)	0.4	0.07–2.2
SDH	308 (52.92)	32 (27.12)	3	1.9–4.7
SAH	194 (33.33)	51 (43.22)	0.66	0.43–0.98
Contusion	58 (9.97)	16 (13.56)	0.71	0.39–1.3
Skull fracture	18 (3.09)	17 (14.41)	0.19	0.09–0.38
Outcomes				
Change in neurologic status	54 (5.54)	1 (0.66)	8.8	1.2–64.0
CT scan progression	73 (7.49)	[c]		
Neurosurgical intervention/death/CMO	78 (8.0)	10 (6.6)	1.13	0.53–2.4
Disposition				
Discharged home from ED	97 (9.95)	40 (26.49)	0.31	0.2–0.47
ED observation unit stay	201 (20.62)	34 (22.52)	0.89	0.6–1.3
Floor admission	528 (54.15)	56 (37.09)	2	1.4–2.9
Intensive care unit admission	147 (15.08)	20 (13.25)	1.2	0.7–1.9
Left against medical advice	2 (0.21)	1 (0.66)	0.3	0.03–3.4

RHCT – repeat head CT, EDH – epidural hematoma, SDH – subdural hematoma, SAH – sub-arachnoid hemorrhage. CMO – comfort measures only.

[a] Fisher exact test.

[b] *t*-Test.

[c] No repeat CT.

Table 2

Comparison of variables in patients with composite outcome of "worsening CT, change in neurologic status, need for neurosurgery or death/CMO" versus patients without composite outcome.

Variable	Patients and RHCT without composite outcome N = 811	Patients and RHCT with composite outcome N = 164	OR	95% CI
	Number (%)	Number (%)		
Age (mean, years)	59.7	64.2	0.02[a]	
Hospital length of stay (days)	3.6	8.3	<0.0001[a]	
Sex (M)	464 (57.2)	107 (65.2)	1.4	1.0–2.0
Past medical history				
Alcohol or drug use	120 (14.8)	32 (19.51)	1.4	0.9–2.2
Hypertension	318 (39.21)	66 (40.24)	1	0.7–1.5
Aspirin use	260 (32.06)	63 (38.31)	1.3	0.9–1.9
Warfarin use	87 (10.73)	28 (17.07)	1.7	1.1–2.7
Clopidogrel/other antiplatelet	36 (4.44)	12 (7.32)	1.7	0.9–3.3
Mechanism of injury				
Fall	573 (70.65)	118 (71.95)	1.1	0.7–1.5
Assault	90 (11.1)	15 (9.15)	0.8	0.5–1.4
Motor vehicle collision	50 (6.17)	7 (4.27)	0.7	0.3–1.52
PedStruck	40 (4.93)	8 (4.88)	1	0.5–2.2
Motorcycle collision	17 (2.1)	6 (3.66)	1.8	0.7–4.6
Bicycle accident	29 (3.58)	5 (3.05)	0.8	0.3–2.2
Glasgow Coma Score				
15	692 (83.33)	115 (70.12)	0.4	0.3–0.6
14	92 (11.34)	26 (15.85)	1.5	0.9–2.3
13	27 (3.33)	23 (14.02)	4.7	2.6–8.5
CT lesions (combined, totals not percentage				
EDH	45	9		
SDH	456	128		
SAH	418	63		
Contusion	222	52		
Skull fracture	147	29		
CT lesions (isolated, percentages)				
EDH	2 (0.25)	2 (1.22)	5	0.7–35
SDH	240 (29.59)	68 (41.46)	1.7	1.2–2.4
SAH	183 (22.56)	11 (6.71)	0.25	0.13–0.5
Contusion	49 (6.04)	9 (5.49)	0.9	0.4–1.9
Skull fracture	14 (1.73)	4 (2.44)	1.4	0.5–4.4

RHCT – repeat head CT, EDH – epidural hematoma, SDH – subdural hematoma, SAH – sub-arachnoid hemorrhage. CMO – comfort measures only.

[a] *t*-Test.

to initial presentation and CT results. These patients did receive a repeat head CT for preoperative planning (ICU versus floor level of care determination and timing of the planned surgery). The remaining 935 patients received were monitored for neurologic changes for an interval and then underwent RHCT. Nine patients (0.97% 95 CI 0.4–1.8) received a neurosurgical intervention, 6 (0.64% 95 CI 0.2–1.4) of whom experienced neurologic decline between their initial and repeat head CT scans. In 3 (0.31% (95 CI 0.1–0.9) patients, progression of hemorrhage on the RHCT without neurologic deterioration resulted in a neurosurgical interventions. Only one of these patients had an initial GCS of 15. All 3 of these patients had a subdural hemorrhage >1 cm. More clinical details regarding these 3 patients is listed in Table 4. There were 305 RHCT

scans performed in order to prompt one neurosurgical intervention that would not have been otherwise detected.

There were 683 patients who had an initial GCS of 15 with no change in RHCT, neurological decline, or neurosurgical intervention. In our entire 975 patients (including those who underwent neurosurgical intervention there were a total of 1840 repeat scans (2.7 CT scans per patient) during their entire hospital admission. The mean time from first CT to the repeat head CT was 7.6 h (range 3.4–52.4 h). One patient underwent repeat imaging that was delayed by multiple factors including a lengthy premedication period require for a concurrent CT angiogram of the head and spine. Patients on anticoagulation and/or antiplatelet medications had a mean of 3.3 head CT scans (range 2–14) while patients not on those medications had a mean of 2.9 head CT scans (range 2–13), p < .0001. The high number of repeat CT scans in some patients includes scans performed post operatively up to discharge. New neurologic complaints or signs occurred in 5.5% of patients and progression of CT (no matter how small or clinically relevant)

Table 3
Explanation and clarification of study outcome variables.

	n	%
Reasons why patients did not undergo repeat head CT		
n = 151		
Neurosurgery recommended repeat CT for exam changes only	103	68.2
Trauma service deferred repeat	16	10.6
Family discussion and patient was comfort care only	1	0.7
Skull fracture was primary lesion and no repeat CT needed	22	14.6
Patient left against medical advice or before completing evaluation	1	0.7
Patient went to operating room directly from ED	8	5.3
Reasons why patients who went to OR had a repeat CT scan		
n = 49		
Plan for OR but repeat CT to document stability	39	79.6
CT angio or CT venogram requested	5	10.2
Initial non operative plan changed to operative	3	6.1
Outside hospital did not send images with patient	1	2.0
Neurosurgery wanted CT right before OR for planning	1	2.0
Neurosurgical procedures performed		
n = 66 (patients with and without repeat CT)		
Acute craniotomy (<24 h after ED presentation)	21	31.8
Delayed craniotomy (≥24 h after ED presentation)	10	15.2
Acute burr hole drainage	6	9.1
Delayed burr hole drainage	18	27.3
Depressed skull fracture management	11	16.6
Events coded as neurologic deterioration		
n = 54		
Lethargy/somnolence	26	48.2
Confusion	10	18.5
Agitation	9	16.7
New focal deficit	7	12.9
Seizure	2	3.7

occurred in 7.5% of patients. However, the combination of new neurologic complaints with associated with CT progression was uncommon (1.2%) and the need for neurosurgical intervention was rare (0.3%). New neurologic complaints (see Table 3) can be nonspecific and more attributable to age and hospital environment, underlying medical conditions leading the trauma or medications administered as not related to an intracranial hemorrhagic burden. As such, the number of patient needed to CT after a patient had a neurologic complaint that eventually resulted in a neurosurgical procedure was 52.
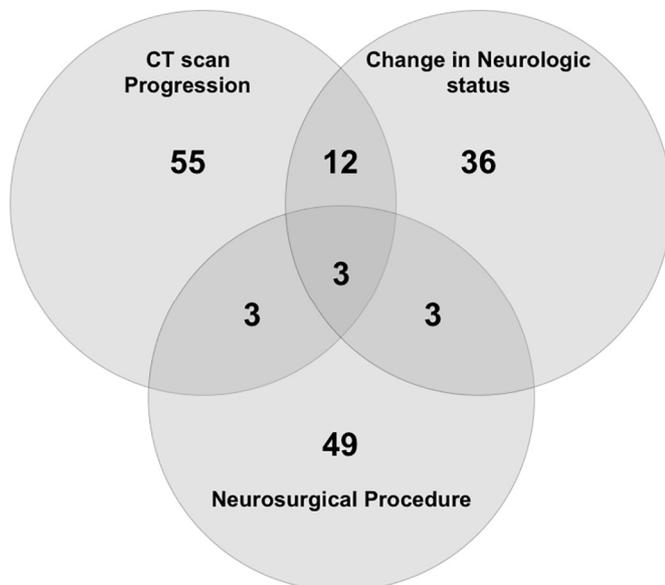

Fig. 1. Venn diagram representing overlap of patients with CT progression, new neurologic events and need for neurosurgery.

4. Discussion

In the largest cohort of patients with mild traumatic intracranial hemorrhage undergoing repeat CT scans to date, our results suggest that RHCT is rarely associated with intervention in the absence of change in neurologic exam. There were three patients who had a RHCT that prompted neurosurgical intervention; all of these patients had an initial subdural hematoma larger than 1 cm.

Our results are in agreement with similar studies investigating the utility of repeat CT scans in patients with TIH. A recent retrospective study examined the effects of a protocol to forego RHCTs in patients with an initial GCS of 15, instead observing them for neurological deterioration. This protocol showed no major negative outcomes, including no neurosurgical interventions, few return visits, and no deaths [3]. Moreover, two other meta-analyses of 1630 and 2693 patients each showed independently that in patients with mTIH, neurologic decline predicted neurosurgical interventions significantly more than RHCT results. In these studies, neurologic decline was defined broadly as observing for symptoms such as persistent headaches, fall in Glasgow Coma Scale (GCS) score, vomiting, or new focal neurological deficits [4,15]. Although these symptoms were not analyzed separately, any neurological decline predicted neurosurgical intervention in as high many as 5.2% of patients in contrast to 0.45% of patients predicted by RHCT results [4]. Further, 42.9% of patients who had neurological decline prompting a repeat head CT received a neurosurgical intervention [15]. Several studies from the trauma literature have also concluded that a RHCT in this low risk group offers marginal benefit over observation for neurologic deterioration, even in patients taking anti-platelet or anti-coagulation medication [19-21]. This study validates several other similar studies (prospective, retrospective, and meta-analyses) and further supports that the rate of neurosurgical intervention based on RHCT in the absence of a new neurologic sign or symptom is vanishingly small (0.3%).

Other studies advocate the use of repeat head CT scanning [15,19,22,23] in patients with TIH. The differences between our conclusions and these reports reflect a difference in study populations. Our cohort reflects all patients with mTIH presenting to an emergency department, while those studies only included admitted patients. Our study population better reflects the type of patient seen in the ED as it also includes individuals placed in an observation unit and discharged directly from the ED. In addition, we included CT scans performed at outside institutions in cases of a transfer. The head CT performed on arrival to the ED to document stability represents the second scan. In other studies that include transferred patients, the timing of the first scan is not clearly noted, so the RHCT studied may actually be a third cranial CT scan.

We examined variables associated with our composite outcome. While one may expect patients on anticoagulation or those on antiplatelet agents to be higher risk for our composite outcome in RHCT, that was not the case. Patients with coagulopathies underwent aggressive reversal with vitamin K, fresh frozen plasma or platelet transfusions, depending on their preinjury medications. Repeat CT scan was then performed after these interventions corrected the coagulation abnormality and may have blunted any progression of RHCT or symptoms. The logistic regression analysis provided variables that may be useful for further studies designed to create a clinical decision rule to help select patients for RHCT.

5. Limitations

This study's retrospective nature limits its ability to determine causality, namely if the findings on RHCT or neurological deterioration led to neurosurgical management. In addition, its origin at a single academic center in which all patients received a neurosurgery consult does not necessarily carry over to community or other academic centers. We utilized progression of hemorrhage as a binary clinical endpoint, and this doesn't reflect changes in size or development of mass

Table 4

Patients who had CT progression and neurosurgical procedure in the absence of new neurologic symptoms.

Patient	Description	Time from CT #1 to CT #2	First CT findings	Second CT findings	Procedure
1	75F with fall GCS 15	4.6 h	SDH 9.7 mm × 6.5 mm × 13 mm	Increased to 13 mm × 9 mm × 14 mm	Craniotomy
2	69F on asa, fall GCS 14	6.3 h	SDH 29 mm 9 mm midline shift	Now extended over occipital lobe	Burr hole
3	75F on asa, warfarin, fall GCS 14	9.3 h	SDH 10 mm	Increased to 13 mm with 9 mm shift	Craniotomy

effect. Finally, clinical decline may also be somewhat unrelated to the mTIH, given the possibility of elderly patients become more confused or agitated in a hospital environment prompting the ordering of a CT scan to rule out worsening intracranial findings. Finally, while the use of RHCT is common at this clinical site, it may not be as frequently used in other departments. However, the frequency of literature on the topic seems to indicate that it is a relatively common practice.

6. Conclusion

Repeat head CT in patients with mTIH rarely leads to a neurosurgical operative intervention in the absence of any neurologic deterioration. The number of patients needed to scan to identify this rare event is 305. This evidence may form the basis for safely proceeding to the next step, a randomized controlled trial for patients with isolated mTIH between obtaining a RHCT and simply observing for neurological decline.

Disclosures

None of the authors have conflicts of interest or disclosures.

Author contributions

Jonathan van Ornam, data collection, manuscript preparation.
Peter Pruitt, data collection, manuscript preparation.
Pierre Borczuk, PI, data collection, analysis, manuscript.

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