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Should Infants with Blunt Traumatic Brain Injuries and Intracranial Hemorrhage Have Routine Repeat Imaging?

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ABSTRACT

Introduction. The practice of repeat head CT imaging in infants as a distinct population is poorly studied. The purpose of this study was to evaluate the incidence and utility of repeat head CT in the infant population.

Methods. A 10-year retrospective review was conducted of infants with blunt traumatic head injuries (N = 50) that presented to a trauma center. Information from the hospital trauma registry and patient medical records were extracted regarding the size and type of injury, number and results of computed tomography (CT) imaging, changes in neurological exams, and any interventions that were required.

Results. Most patients (68%) had at least one repeat CT, with 26% showing progression of hemorrhage. Decreased Glasgow Coma Scale was associated with having repeat CT scans. Nearly one in four infants had a change in management associated with repeat imaging. Repeat CT scans resulted in operative interventions in 11.8% of cases and longer intensive care unit (ICU) stays in 8.8% of cases. Repeat CT scans were associated with increased hospital length of stay, but not with increased ventilator days, ICU length of stay, or mortality. Worsening bleeds were associated with mortality, but not with other hospital outcomes.

Conclusions. Changes in management following repeat CT appeared to be more common in this population than in older children or adults. Findings from this study supported repeat CT imaging in infants, however, further research is needed to validate results of this study.
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INTRODUCTION

Blunt traumatic brain injuries (TBI) are evaluated with non-contrasted computed tomography (CT) of the head. When an intracranial hemorrhage is identified, it often is followed with routine repeat head CT (RHCT) within 24 hours to evaluate for injury progression.[1,2] However, the clinical significance of minute progression, now more easily detected due to improvements in imaging, has not been proven.

Initial CT imaging is accepted widely, but routine follow-up imaging has come into question in adult and pediatric populations as more is learned about the questionable benefit and known risks of ionizing radiation. Brenner and colleagues[3] evaluated cancer risk from a single head CT in children and found the life-time risk of death from cancer to be 10-fold higher than in an adult. Radiation exposure in children also has deleterious effects on cognition in adulthood and increases risk for cataracts. These scans are expensive and potentially dangerous; an effect more pronounced in younger populations.

RHCT in adult patients with severe traumatic brain injury is justified.[4] In contrast, patients with mild to moderate brain injuries have not been shown to benefit from routine repeat imaging in adults.[4,5] RHCT in neurologically stable adult patients is safe,[6] but rarely results in changes in care.[7,8] Retrospective studies in children have been shown to correlate with the adult findings.[9,10] However, no standardized imaging guidelines exist for any population with regard to repeat imaging.[4,7,11]

Infants represent a unique population, even among children. The rate of assault in infants (including non-accidental trauma, NAT) is significantly higher, and the incidence of motor vehicle crash as a mechanism is much lower.[12] Infants cannot speak for themselves, making caretakers an integral part of their evaluation under most circumstances. However, caretakers in cases of suspected NAT often are not present and/or viewed as less reliable. In addition, Glasgow Coma Scale (GCS) score is calculated using different metrics in children under one year of age.[14] While evaluating the presence of some neurologic symptoms (e.g., vomiting, seizures) is very plausible, subtler symptoms are impossible to detect (e.g., nausea, dizziness). These dissimilarities bring validity to studying infants as a discrete population.

The unique nature of the infant population in reference to traumatic brain injuries warranted dedicated attention to the incidence and progression of intracranial hemorrhage on repeat imaging. Therefore, the purpose of this investigation was to evaluate the utility of RHCT in an infant population.

METHODS

A 10-year retrospective review was conducted of all trauma patients aged less than or equal to one year of age who presented with blunt traumatic head injury at an American College of Surgeons verified level II pediatric trauma center between January 1, 2005 and December 31, 2014. The data set for this study originated as part of a sub-analysis from a previous study.[9] Subjects who were not imaged or who had injuries more than 24 hours prior to presentation were excluded. Subjects transferred from other facilities were not excluded automatically.

Data collected included patient demographics, injury severity (injury severity score [ISS], GCS score), mechanism of trauma, type and size of intracranial hemorrhage, number of repeat scans and findings, change in GCS score or neurological examination, management changes following CT scans, interventions required (transfusion, intracranial pressure [ICP] monitor placement, neurosurgery), intensive care unit (ICU) and ventilator utilization, hospital length of stay, mortality, and discharge disposition. Information not readily available from the trauma registry was extracted from the patient medical records; available electronically and/or in hard copy. This study was approved for implementation by the Institutional Review Board of Via Christi Hospitals Wichita, Inc.

Statistical Analysis. Comparisons of categorical data were conducted using chi-squared analysis with Fisher's exact correction for comparisons with expected counts less than five in any cell. Comparisons of continuous data were done using Mann Whitney U tests since these variables were not expected to have a normal distribution.

Univariate analyses were conducted using all available observations, except where noted. All statistical tests were two-sided and analyses were considered significant when the resultant p value was ≤ 0.05. All analyses, except where noted, were conducted using SPSS release 19.0 (IBM Corp., Armonk, New York).

RESULTS

A total of 50 patients met inclusion criteria for our study. The average patient age was 4.3 months, the majority were male (64%), and ISS values were well distributed in our population (Table 1). More than half of infants sustained mild brain injuries with GCS 13-15 (60%); the others had moderate injuries with GCS 9-12 (20%), or severe injuries with GCS less than 9 (20%). The most common mechanism of injury was abuse (70%, n = 35) followed by falls (22%, n = 11) and motor vehicle crashes (8.0%, n = 4).

Table 1. Demographics and injury severity from head injury in infants.

Variable	Number (%)
Number of observations	50 (100%)
Age (months)*	4.3 ± 3
Male sex	32 (64%)
Injury Severity Score	
≤ 15	20 (40%)
16 – 24	17 (34%)
≥25	13 (26%)
Glasgow Coma Scale Score	
≤ 8	10 (20%)
9-12	10 (20%)
13-15	30 (60%)
Polytrauma	11 (22%)

*Mean ± SD

Approximately one-third of patients showed a decline in GCS score after their initial assessment (Table 2). Nearly all patients (96%) were admitted to the ICU and nine patients (18%) went to the operating room as a result of their injury. Most patients (68%, n = 34) had at least one repeat CT scan. The repeated scans were obtained a median of 18 hours after initial imaging. Eight of the 34 patients (23.5%) had a change in management due to the results of a repeat CT scan. Of those, three (8.8%) were kept longer in the ICU, two (5.9%) received hypertonic saline, and four (11.8%) had operative interventions. As transfer patients were included, it was possible that imaging was repeated to allow for initial evaluation at our facility.

The incidence of repeating a CT scan was not associated significantly with the size of the intracranial bleed on the initial scan when stratified by small (less than 1 cm) and large (at least 1 cm) bleed sizes (Table 3). In evaluating specific bleed types, the only type of bleed identified on the initial scan that was associated with patients receiving a repeat scan was subarachnoid hemorrhage (no repeat scan, n = 1 (6.3%) vs. RHCT, n = 12 (35.3%); p = 0.039). As expected, repeat CT scans were associated with decreased GCS score (41% vs 13%; p = 0.043). However, vomiting, seizure activity, and retinal hemorrhage were not associated with obtaining a RHCT.

Table 2. Patient characteristics from head injury in infants.

Variable	Value*
Number of observations	50 (100%)
Number with decrease in Glasgow Coma Scale score	16 (32%)
Admitted to intensive care unit	48 (96%)
Transfused blood products in first 24 hours	5 (13%)
Had intracranial pressure monitoring	3 (6%)
Had a repeat CT	34 (68%)
Time to 1st repeat CT (hours)	18 (12, 25.8)
Change in management based upon repeat CT findings	8/34 (23.5%)
Number of repeat scans	1.0 (1.0, 1.25)**
Went to operating room	9 (18%)

*Data presented as number (%) or median (interquartile range).
**For those with repeated scans, the minimum number of repeated images was one with a maximum of six.

Receiving a repeat scan was not associated with going to the operating room or ICU, the length of ICU stay, or the number of days on mechanical ventilation (Table 4). Repeat imaging, however, was associated with a longer hospital stay (6.5 vs. 2.5 days; p = 0.045). There were no differences in mortality or discharge disposition between patients with and without repeat imaging.

Table 3. Comparison of size and type of head bleed, and neurologic evaluation of patients with or without repeat imaging.

Variable	No Repeat CT*	Repeat CT*	p Value
Number of observations	16 (32%)	34 (68%)	---
Size of intracranial hemorrhage**			0.845
Small (< 1cm)	12 (80%)	28 (82%)	
Large (≥ 1cm) or diffuse	3 (20%)	6 (18%)	
Decrease in Glasgow Coma Scale score	2 (13%)	14 (41%)	0.043
Vomiting	2 (12.5%)	4 (11.8%)	0.941
Seizure activity	5 (31%)	13 (38%)	0.631
Retinal hemorrhage	5 (31%)	15 (44%)	0.386

*Data presented as number (%).
** Missing data for one subject

Table 4. Comparison of patient outcomes for those with or without repeat imaging.

Variable	No Repeat CT*	Repeat CT*	p Value
Number of observations	16 (32%)	34 (68%)	---
Went to the operating room	1 (6%)	8 (24%)	0.240
ICU admission	14 (87.5%)	34 (100%)	0.098
Intensive care unit days	2.5 (1,5.3)	5 (2,10)	0.077
Ventilator days	3 (2, na)†	3.5 (2.8, 8.3)	0.500
Hospital length of stay (days)	2.5 (2, 8.3)	6.5 (3, 13.3)	0.045
Survival status			0.163**
Survived	16 (100%)	29 (85%)	
Died	0 (0%)	5 (15%)***	
Discharge status			0.102
Home or home w/ health care or acute care	9 (56%)	23 (79%)	
Foster care/child protective service or other	7 (44%)	6 (21%)	

*Data presented as number (%) or median (interquartile range).
** Fisher's exact test used when the smallest expected cell count < 5.
***Includes two patients that were discharged to hospice.
†Only two patients without repeat scans were on mechanical ventilation.

Of the 34 patients who had a repeat CT scan, 10 showed a progression or worsening of their hemorrhage (Table 5). In evaluating initial bleed size and neurologic indicators, progression of an intracranial hemorrhage was associated only with decreased GCS score, although this did not reach statistical significance (p = 0.054). In evaluating hospitalization utilization and outcomes, worsening hemorrhage was associated with increased ventilator days and higher mortality (50% vs. 0%; p = 0.001; Table 6). No other hospital outcome was associated with increased hemorrhage on repeat CT.

Table 5. Comparison of size of head bleed and neurologic evaluation of patients who underwent repeat head CT with or without a subsequent increase in size of intracranial hemorrhage.*

Variable	No Increase in Bleed Size	Increased Bleed Size	p Value
Number of observations	24 (71%)	10 (29%)	---
Went to the operating room	6 (25%)	2 (20%)	>0.999
Size of intracranial hemorrhage			0.328
Small, < 1 cm	21 (88%)	7 (70%)	
At least one ≥ 1 cm or diffuse	3 (13%)	3 (30%)	
Decrease in Glasgow Coma Scale score	7 (29%)	7 (70%)	0.054
Vomiting	4 (16.7%)	0 (0.0%)	0.169
Seizure activity	10 (42%)	3 (30%)	0.704
Retinal hemorrhage	12 (50%)	3 (30%)	0.451

*Data presented as number (%).

Table 6. Comparison of patient outcomes for those with or without worsening hemorrhage.

Variable	No Increase in Bleed Size*	Increased Bleed Size*	p Value
Number of observations	24 (71%)	10 (29%)	---
Intensive care unit days	5.5 (2,9)	4 (2.75,14)	0.909
Ventilator days	0 (0,0.75)	3 (1.5,6)	0.003
Hospital length of stay (days)	7 (2.25,12.5)	5.5 (3,14)	0.970
Survival status			0.001**
Survived	24 (100%)	5 (50%)	
Died	0 (0.0%)	5 (50%)***	

*Data presented as number (%) or median (interquartile range).
** Fisher's exact test used when the smallest expected cell count < 5.
***Includes two patients that were discharged to hospice.

There were nine patients who required surgical intervention. The majority of these patients had a GCS less than 15 on presentation (55.6%, n = 5), two of which had a GCS score ≤ 8 (22.2%). Three of the nine (33.3%) had a decrease in GCS after hospital admission. All but one patient that went to the operating room had a repeated scan. Of the eight patients that received a repeat scan and went to the operating room, two showed an increase in the size of intracranial hemorrhage. In comparison to small bleeds (those less than 1 cm, n = 40), large bleeds (those 1 cm or greater in size, n = 9) were associated more often with operative intervention in this population (n = 5, 13% vs n = 4, 44%; p = 0.046). Of those patients that died, all died of their TBI. Intracranial hemorrhage progression on repeat CT scans was not associated with need for operative management (no progression = 20% vs. progression = 25%; p = 0.754).

DISCUSSION

Patients with TBI are resource intensive, requiring trauma and neurosurgical evaluation in addition to admission to an ICU. Decreasing the number of CT scans received would reduce the cost of their care as well as the risks associated with radiation exposure.

Research focused on the adult patient demonstrated that those without neurologic change do not benefit from RHCT; that is repeat imaging did not lead to changes in care in such a population.[7,8] Those with mild TBI (defined as a GCS ≥ 13) gained minimal benefit from repeat imaging, even in studies in which the authors' continued to endorse RHCT.[5] Aziz et al.[14] similarly found RHCT did not result in management changes in the pediatric population when focusing on mild or moderate head injuries; the authors recommended forgoing RHCT in favor of serial neurologic exams if GCS remained greater than eight. However, this and many other studies looking at the pediatric population excluded infants. The rationale for excluding infants often was not stated explicitly, but the differences in how GCS was calculated, and the limits of any subjective data were among the reasons they may be omitted. To our knowledge, our study was the first to investigate this population exclusively.

Our finding that 29% of all intracranial hemorrhages progressed on repeat imaging was consistent with previous studies.[6,15] Compared to studies of older children and adults, more infants had changes in management based on RHCT findings.[9,14] Hill et al.[9] found that only 1% of all pediatric patients < 18 years of age required neurosurgical intervention after RHCT. Similarly, Joseph et al.[15] found that 1.4% of adult patients with TBI required neurosurgical intervention after RHCT. Of those patients that required surgical intervention, 75% had signs of neurologic decline that indicated their RHCT. By comparison, 16% of our infant population required surgical intervention after RHCT. This indicated that in infants, routine RHCT protocols are founded and find worsening intracranial hemorrhages that require surgical intervention.

Other investigators have noted changes in neurologic examinations correlated to worsening findings on CT scan. Aziz et al.[14] found that 85% of the repeated CT images that were due to changes in neurological status showed bleed progression compared to 18% of routine repeated CT images. We found this to hold true with GCS, but other changes like vomiting, seizure, and retinal hemorrhage did not correlate to worsened bleeding and may not warrant such repeat imaging. However, in this population, it is difficult to feel comfortable not reimaging a known bleed. Some physical exam findings, including neurologic findings such as headache and nausea that can be communicated easily by adults and adolescents, are not collectable in infants. While parents can provide some of this information, the high incidence of NAT in this population may cause parents to be viewed as a less reliable source of information.[12]

Limitations. Our study findings should be viewed in light of the limitations of our study. First, our findings were limited by the retrospective nature of our investigation. While a prospective study would provide greater control of variables and a higher level of evidence, preliminary retrospective studies are crucial for justifying the feasibility and need for prospective work. Second, the small size of our study sample limited our ability to isolate any specific bleed type or population that would be observed safely without repeat imaging. Finally, we were limited by the data available in the hospital records. Ideally, we would like to follow these patients long-term to differentiate whether RHCT changes outcomes in infants who experience blunt traumatic brain injuries into childhood and beyond. Finally, more research needs to be done to determine which infants would be best served by obtaining RHCT.

CONCLUSIONS

The evidence is mounting in support of less imaging in older children and adults with blunt traumatic injuries; however, a paucity of data exists regarding infants. We found that infants were reimaged as frequently as older children and adults in other studies, but that management changes after RHCT were made more frequently in this population. Decreased GCS correlated with worsened bleeding, but vomiting, seizure, and retinal hemorrhage did not. Findings from this study supported repeat CT imaging in infants; however, further evidence is needed to validate the results of this study. Prospective and larger studies focused on specific populations and indications for repeat CT scans are needed to support the development of clinical guidelines for repeat imaging.

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