



# Hospital Variation in Cervical Spine Imaging of Young Children With Traumatic Brain Injury

*M. Katherine Henry, MD; Mark R. Zonfrillo, MD, MSCE; Benjamin French, PhD; Lihai Song, MS; Chris Feudtner, MD, PhD, MPH; Joanne N. Wood, MD, MSHP*

From the Division of General Pediatrics (Drs Henry, Feudtner, and Wood), Center for Pediatric Clinical Effectiveness (Drs Henry, Feudtner, and Wood, and Ms Song); The Children's Hospital of Philadelphia, Philadelphia, Pa, and PolicyLab, The Children's Hospital of Philadelphia, Philadelphia, PA (Dr Wood and Mr Song); Department of Emergency Medicine and Injury Prevention Center, Alpert Medical School of Brown University and Hasbro Children's Hospital, Providence, RI (Dr Zonfrillo); Department of Biostatistics and Epidemiology, University of Pennsylvania, Philadelphia, Pa (Dr French); and Department of Pediatrics, Perelman School of Medicine at the University of Pennsylvania, Philadelphia, Pa (Drs Feudtner and Wood)

Conflict of Interest: The authors declare that they have no conflict of interest.

Address correspondence to M. Katherine Henry, MD, The Children's Hospital of Philadelphia, 3535 Market St, Room 1494, Philadelphia, PA 19104 (e-mail: [henrym2@email.chop.edu](mailto:henrym2@email.chop.edu)).

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## ABSTRACT

**OBJECTIVE:** Cervical imaging practices are poorly understood in young children with traumatic brain injury (TBI). We therefore sought to identify child-level and hospital-level factors associated with performance of cervical imaging of children with TBI from falls and abusive head trauma (AHT) and to describe across-hospital variation in cervical imaging performance. We hypothesized that imaging decisions would be influenced by hospital volume of young injured children.

**METHODS:** We performed a retrospective study of children younger than 2 years of age with TBI from 2009 to 2013 in the Premier Perspective Database. After adjustment for observed patient characteristics, we evaluated variation in advanced cervical imaging (computed tomography or magnetic resonance imaging) in children with AHT and TBI from falls.

**RESULTS:** Of 2347 children with TBI, 18.7% were from abuse and 57.1% were from falls. Fifteen percent of children with TBI underwent advanced cervical imaging. Moderate or severe

head injuries were associated with increased odds of cervical imaging in AHT (odds ratio 7.10; 95% confidence interval 2.75, 18.35) and falls (odds ratio 2.25; 95% confidence interval 1.19, 4.27). There was no association between annual hospital volume of injured children and cervical imaging performance. The adjusted probability of imaging across hospitals ranged from 4.3% to 84.3% in AHT and 3.1 to 39.0% in TBI from falls ( $P < .001$ ).

**CONCLUSIONS:** These results highlight variation across hospitals in adjusted probability of cervical imaging in AHT (nearly 20-fold) and TBI from falls (over 10-fold) not explained by observed patient characteristics. This variation suggests opportunities for further research to inform imaging practices.

**KEYWORDS:** accidental falls; child abuse; spinal injuries; traumatic brain injury

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## WHAT'S NEW

Statistically significant variation in cervical imaging of children <2 years of age with traumatic brain injury from falls and abuse exists across hospitals. This study highlights opportunities for further research to inform the role of cervical imaging in this young population.

TRAUMATIC BRAIN INJURY (TBI), a leading cause of death in children,<sup>1</sup> can co-occur with injuries to the cervical spine.<sup>2–4</sup> Recent evidence suggests that cervical spine injuries occur more commonly than previously recognized in certain subpopulations of children with TBI, specifically in young children with abusive head trauma (AHT).<sup>5–7</sup> Imaging decisions therefore need to be tailored to the individual child's age and mechanism of trauma. Further understanding of current practices and

indications for cervical imaging specifically in young victims of TBI less than 2 years of age is needed due to the distinct mechanisms of TBI in young children,<sup>8</sup> anatomic differences of the young developing spine,<sup>3,9</sup> and the diagnostic challenges posed by this young and often preverbal population.<sup>10</sup>

Health services research can help to better describe current imaging practices for young children with TBI and to motivate and potentially guide improvement efforts by examining excessive variation in imaging practices across hospitals (meaning variation above and beyond that due to differences due to patient characteristics) and by testing whether certain types of hospitals, or hospitals that care for different volumes of patients, systematically image these children differently. Regarding variation in practice, we know that performance of cervical computed tomography (CT) among children with TBI younger than

18 years ranges from 0.9% to 59.4% across select children's hospitals.<sup>11</sup> We do not know what this range is for young children with TBI, especially after adjustment for patient characteristics. Regarding differences across types of hospitals, in prior work describing cervical imaging of children younger than 3 years presenting with blunt trauma, level 1 adult trauma centers and pediatric trauma centers in adult hospitals were more likely to obtain cervical CT than level 1 pediatric trauma centers in children's hospitals.<sup>10</sup> Given that non-children's hospitals care for 89% of pediatric trauma victims with intracranial injuries,<sup>12</sup> examining care provided in these institutions is important. Regarding hospital volume, these differences suggest that hospitals that care for larger volumes of injured children may image less. Indeed, a study of 14 hospitals found increased pediatric volume was associated with decreased performance of cervical CTs in injured children.<sup>13</sup>

Accordingly, the purpose of this study was to describe and analyze the use of advanced cervical imaging by TBI mechanism in children younger than 2 years of age. Our objectives were to identify child-level and hospital-level factors associated with decision to obtain advanced cervical imaging in young children evaluated for the most common mechanisms of TBI (falls and AHT); describe variation in imaging practices across hospitals after accounting for differences in patient characteristics; and evaluate the association of hospital volume of young injured patients with the odds of obtaining advanced cervical imaging. We hypothesized that hospitals treating a higher volume of young injured children may have more experience examining young children and therefore perform less cervical imaging in children with TBI from falls. Because hospitals that care for more injured children may be more familiar with possible abuse-related injuries, we hypothesized that they would obtain more cervical imaging in cases of AHT.

## METHODS

### DATA SOURCE

We utilized the Premier Perspective Database (PPD; Premier Inc, Charlotte, NC) for this study. The PPD is an all-payer administrative database that captures approximately 20% of US hospitalizations and 5.5 million annual discharges from more than 500 hospitals.<sup>14–16</sup> The PPD provides detailed information on imaging performed during each encounter in addition to patient demographics, diagnosis and procedure codes, and hospital characteristics. Imaging results are not available in the PPD. This study of deidentified data did not meet the definition of human subject research and did not require institutional review board approval.

### COHORT

We selected children less than 2 years of age discharged between 2009 and 2013 from an emergency department (ED) visit, observational stay, or inpatient unit with an International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM), diagnosis of TBI. For our analyses we stratified the cohort by mechanism of injury:

falls, motor vehicle crashes (MVCs), and AHT. For our definition of AHT, we adapted the Centers for Disease Control and Prevention AHT algorithm<sup>17</sup> by removing ICD-9-CM codes that did not explicitly reference head injury in order to focus our sample on children with AHT and definitive intracranial injuries. To capture the initial presentation of an injury, we included the first TBI encounter for each patient in the study time period. Children transferred to other institutions within 3 days and all children transferred from outside facilities were excluded because imaging could have been performed before or after transport and could thus lead to underestimates of imaging. Hospitalizations related to birth and children discharged to rehabilitation facilities or hospice within 3 days were excluded. To facilitate valid hospital volume comparisons, we included only hospitals that reported both ED and inpatient data.

### OUTCOME

Our primary outcome of interest was a binary indicator for advanced cervical imaging. To ensure inclusion of all possible advanced cervical imaging, this outcome was defined as performance of a CT or magnetic resonance imaging (MRI) of the cervical spine, full spine, or spine without specified location. Some hospitals relied exclusively on CT for cervical imaging of children with TBI, and others used a combination of CT or MRI. We therefore elected to use this combined outcome because selection of modality was likely influenced by availability and hospital norms in addition to concerns for specific injuries.

The focus of this work was not the use of cervical radiographs because their role as the sole imaging modality to rule out injury in young trauma victims with a decreased Glasgow Coma Scale or with unreliable clinical exams is unclear.<sup>18</sup> We do, however, describe the percentage of children who underwent cervical plain radiographs, defined as a radiograph of the cervical spine, whole spine, or unspecified spinal region. Skeletal surveys were not included in this definition.

### COVARIATES

Patient-level covariates included age, race (white, African American, Hispanic, or other), sex, insurance status (public, private, or other), and discharge year. Each patient's injury severity was measured with the Maximum Abbreviated Injury Scale (MAIS) severity score of the head.<sup>19</sup> The MAIS is an ordinal scale of injury severity ranging from minor injury (coded as 1) to maximal/untreatable injury (coded as 6) for discrete body regions. Each ICD-9-CM code associated with the encounter was mapped to the 1998 version of the Abbreviated Injury Scale (AIS) codes using the ICDMAP-90 software.<sup>20</sup> To ensure use of current severity scores, these codes were then manually remapped to the most recent AIS 2005/2008 versions and the ICD-9-CM injury descriptions.<sup>19–21</sup> A MAIS score of 0 indicated an injury too nonspecific to categorize. MAIS scores of the head outside the ICD-9-CM range of the MAIS, such as 995.55 (Shaken Baby

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