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Cervical spine injuries in young children: pattern and outcomes in accidental *versus* inflicted trauma

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ABSTRACT

Background: The aim of the study was to compare the cervical spine (c-spine) pattern of injury and outcomes in children below 3 y with a head injury from confirmed inflicted *versus* accidental trauma.

Methods: After Institutional Review Board approval, data were prospectively collected between July 2011 and January 2016. Inclusion criteria were age below 3 y, a loss of consciousness, and any one of the following initial head computed tomography (CT) findings (subdural hematoma, intraventricular, intraparenchymal, subarachnoid hemorrhage, or cerebral edema). A protocol of brain and neck magnetic resonance imaging and magnetic resonance angiography was instituted. Brain and neck imaging results, clinical variables, and outcomes were recorded. Data were compared by *t*-test for continuous and Fisher exact test for categorical variables.

Results: 73 children were identified, 52 (71%) with inflicted and 21 (29%) with accidental trauma. The median age was 11 mo; (range: 1-35 mo). Ten (14%) had c-spine injuries, 7/52 (13%) inflicted, and 3/21 (14%) accidental. The mechanism was shaking for all inflicted and motor vehicle accident or pedestrian struck for accidental c-spine injuries. The inflicted group were significantly younger ($P = 0.03$), had higher Injury Severity Scores ($P = 0.02$), subdural hematomas ($P = 0.03$), fractures ($P = 0.03$), retinal hemorrhages ($P = 0.02$), brain infarcts ($P = 0.01$), and required cardiopulmonary resuscitation ($P = 0.01$). Seven with inflicted trauma died from brain injury (9.5%), one had atlanto-occipital dissociation. Six mortalities (86%) had no c-spine injury. Six with inflicted c-spine injuries survived with neurologic impairment, whereas three with accidental survived without disability, including one atlanto-occipital dissociation.

Conclusions: Compared to accidental trauma, young children with inflicted c-spine injuries have more multisystem trauma, long-term disability from brain injury, and an injury pattern consistent with shaking.

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Introduction

Trauma is the primary cause of morbidity and mortality in children, and the incidence of head injuries is rising.[1] Cervical spine (c-spine) injuries, however, are less common and may be difficult to identify in children with multisystem traumatic injuries.[2] The distribution of injuries differs with age. The immature spine has different anatomic and biomechanical properties than older children that must be differentiated. Younger children generally sustain injuries of the upper spine, with a higher risk of death than older children.[3] Few institutions use a standard pediatric c-spine clearance protocol, although protocols have been shown to decrease the incidence of missed injuries.[4]

Previously, motor vehicle accidents were reported as the main cause of c-spine injury in children.[5] However, autopsy findings in fatal abusive head trauma have found a high incidence of upper cervical spinal injuries.[6] Similarly, the use of magnetic resonance imaging has detected a higher incidence of c-spine injury in young children with inflicted trauma than that was previously appreciated.[7] Many of the c-spine injuries that occur in infants and small children are ligamentous and may not be detected by radiographic and computed tomography (CT) imaging.[8] Detection of c-spine injury may be underdiagnosed due to lack of clinical suspicion, uncertainty as to the mechanism of injury and difficulties in detection with standard radiologic imaging.

The aim of this study was to compare the pattern of c-spine injuries and outcomes for children younger than 3 y with a closed head injury from confirmed inflicted *versus* accidental trauma. By comparing the incidence and patterns of injury between the groups, it is hoped that further understanding of the forces and mechanisms of injury can be obtained and will guide diagnostic algorithms for improving detection of c-spine injuries.

Methods

Cohort

This was an Institutional Review Board (IRB)–approved prospective cohort study (IRB 5100168). The IRB waived the informed consent requirement for this study. Data were collected between July 2011 and January 2016. During the study period, children younger than 3 y, admitted through the emergency department with a loss of consciousness from confirmed inflicted or accidental head trauma, were included. All included children underwent evaluation by the trauma team within 4 h of arrival in the emergency department, supervised by a pediatric surgeon. The participating pediatric surgeon, pediatric neurosurgeon, emergency room pediatrician, forensic pediatrician, pediatric ophthalmologist, and neuroradiologist were all board certified.

For each included case of inflicted trauma, a social services and law enforcement investigation was commenced, and the perpetrator confessed or the abuse was witnessed. Cases that were indeterminate for inflicted trauma as the injury mechanism were excluded. Injuries were identified and documented by pediatricians with a specialty in forensic pediatrics. No bleeding disorders were identified. All included children underwent an ophthalmic exam by a pediatric ophthalmologist and retinal hemorrhages were documented if identified.

Imaging protocol and variables

CT head

All included children had a noncontrast head CT scan performed on admission through the emergency department with one of the following findings: a subdural hematoma (SDH), intraventricular, intraparenchymal, or epidural hematoma, as well as subarachnoid hemorrhage, diffuse axonal injury, hypoxic injury, or cerebral edema.[9]

Magnetic resonance imaging brain

One pediatric neurosurgeon and a neuroradiologist reviewed all images and supervised the institution of a magnetic resonance imaging and angiography (MRI)/MRA protocol of the brain, c-spine, and neck vessels within 48 h of admission. A noncontrast head CT is the first-line imaging modality for pediatric head trauma.[8] Early MRI, however, provides better estimation of shear injuries, hypoxic injury, ischemic insults, and the timing of lesions.[10,11]

The brain MRIs included T1 magnetization-prepared rapid acquisition with gradient echo and T2 sequences. In addition, T2 fluid attenuation inversion recovery, weighted imaging, diffusion tensor imaging with diffusion coefficient, and color fractional anisotropy maps were performed.[11,12]

The brain MRI findings at 48 h were categorized as infarction or hypoxic injury. Brain infarction was defined as an area of localized necrosis of brain tissue.[13] Hypoxic injury was defined as brain damage from inadequate brain oxygenation.[13]

MRI c-spine

MRIs of the c-spine included T1, T2, and short tau inversion recovery images. Neck MRA's without contrast included time of flight resonance angiograms of the cervical vasculature to the skull base. Brain MRA's included the vertebrobasilar anatomy with maximum projection and source imaging. Axial T1 with fat suppression, T2 diffusion tensor imaging and resultant average diffusion coefficient, tensor trace, and color fractional anisotropy maps were generated. Any abnormality of the c-spine or neck vessels was documented.

Clinical variables

The details of the trauma mechanism, whether accidental or inflicted, were documented. The recorded variables were gender, Glasgow Coma Scale (GCS),[14] Injury Severity Score (ISS),[15] the lowest recorded systolic blood pressure, the lowest oxygen saturation, blood transfusion administration in the ED, and cardiopulmonary resuscitation (CPR). Respiratory failure or lack of airway protection requiring intubation and ventilation, either before arrival or at presentation to the ED, was documented.