Journal of Pediatric Surgery 50 (2015) 1751–1757

Contents lists available at ScienceDirect

Journal of Pediatric Surgery

journal homepage: www.elsevier.com/locate/jpedsurg

Screening for Pediatric Blunt Cerebrovascular Injury: Review of Literature and a Cost-Effectiveness Analysis☆,☆☆

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ARTICLE INFO

Article history:
Received 22 January 2015
Received in revised form 5 May 2015
Accepted 12 May 2015

Key words:
pediatric trauma
blunt cerebrovascular injury
CT angiography
digital subtraction angiography
cost-effectiveness analysis

ABSTRACT

Background: Timely and accurate screening for pediatric blunt cerebrovascular injury (BCVI) is important in order to administer appropriate anticoagulation therapy thus preventing stroke. The recommended criteria for screening in children are not clear. We performed a systematic review of the literature for screening and management of BCVI in children and designed a cost-effectiveness analysis in order to determine the optimal strategy for managing pediatric BCVI from a societal perspective.
Methods: Comprehensive review of studies citing BCVI in pediatric patients was carried out with data extraction and compilation. An economic evaluation of 5 possible screening strategies was performed by designing a decision tree over a 1-year horizon using parameters derived from literature review. Base case calculations were made to compare cost effectiveness for each strategy. Monte Carlo simulation and extensive sensitivity analyses were performed to examine the robustness of the conclusion against key variables.
Results: Selective anticoagulation therapy in patients with high-risk factors was found to be the most cost-effective strategy and selective computed tomography angiography (CTA) in high-risk patients was the optimal imaging strategy. This conclusion was corroborated by a Monte Carlo simulation of 10,000 iterations. In all sensitivity analyses, selective anticoagulation and selective CTA continue to be the optimal strategy until the risk of anticoagulation complications rises above 3.9%.
Conclusions: Our study demonstrated selective CTA to be the optimal imaging strategy in order to assess BCVI in children. Further studies are needed for more clearly defined screening criteria.

Blunt trauma resulting in injury to the carotid or vertebral arteries (blunt cerebrovascular injury, BCVI) can lead to stroke, often with devastating consequences. The incidence reported in adults is 0.18%–2.7% of all blunt trauma admissions, with higher incidence being reported in patients possessing risk factors and more severe injuries [1,2]. The reported frequency of diagnosis of BCVI in children is lower than in adult centers [3,4].

As in adult patients, motor vehicle collision is the most prevalent mechanism of injury in patients with BCVI [4–8]. However, even low-energy traumatic mechanisms (fall from low heights or blow from heavy objects) have also been shown to account for up to a third of pediatric patients diagnosed with BCVI [4,9,10].

In a systematic review of literature performed in 2008 examining traumatic extracranial carotid artery injuries in children, the diagnosis was made in 97% of patients after the onset of ischemic asymptomatology [11]. Early detection of BCVI by screening and institution of antithrombotic treatment during the initial asymptomatic period have been shown to reduce the incidence of stroke and improve neurological outcomes considerably [12,13].

The 2010 Eastern Association for the Surgery of Trauma management guidelines 1, based on an extensive review of available literature, found no level I evidence for which blunt trauma patients to screen, which imaging modality to use for screening, or what to use for BCVI treatment. Level III evidence was found for using risk factors defined by Denver criteria to screen asymptomatic patients with blunt head trauma for BCVI. A recommendation was made to evaluate pediatric trauma patients using the same criteria as adult population [10]. The detailed grading scale is presented in Table 1.

In view of the limited information currently available, we performed a systematic review of the literature for screening and management of BCVI in children, with a view to designing a cost-effectiveness analysis in order to determine the optimal strategy of managing pediatric BCVI from a societal perspective.

1. Materials and methods

An economic evaluation of 5 possible screening strategies was performed by constructing a decision tree over a 1-year horizon. Parameters

☆ Conflicts of interests: None.
☆☆ Funding: None.
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http://dx.doi.org/10.1016/j.jpedsurg.2015.05.005
0022-3468/

Table 1
BCVI screening criteria [1].

	Near hanging resulting in anoxic brain injury
Injury mechanism	Severe cervical hyperextension/rotation or hyperflexion, particularly if associated with: i) Displaced midface or complex mandibular fracture ii) Closed head injury consistent with diffuse axonal injury Near hanging resulting in anoxic brain injury
Physical signs	Seat belt abrasion or other soft tissue injury of the anterior neck resulting in significant swelling or altered mental status
Fracture in proximity to internal carotid or vertebral artery	Basilar skull fracture involving the carotid canal Cervical vertebral body fracture

for the mathematical model were derived from a comprehensive review of current literature and taking the weighted average among all data reported. The summary of the articles is presented in Table 2. Because no actual patients were involved in this study, approval from the institutional review board was not necessary.

1.1. Model design

The model was constructed using TreeAge Pro Suite 2014 (TreeAge Software, Inc, Williamstown, Mass) starting with a pediatric patient presenting with trauma in the emergency department. Five possible management strategies were considered – (1) selective anticoagulation therapy in patients with BCVI risk factors, (2) selective computed tomography angiography (CTA) or (3) digital subtraction angiography (DSA) screening in patients with BCVI risk factors, and (4) CTA in all or (5) DSA in all patients. Mortality from exsanguination was as reported in literature, and these patients were assumed to undergo no further treatment and thus had no additional costs.

For the first strategy, complications from anticoagulation therapy were considered in high-risk patients. No costs were incurred in patients without risk factors because they underwent no imaging or anticoagulation, but BCVI patients in this group were assumed to be undetected, with a higher risk of stroke.

In each imaging strategy, 4 possible results were included, true positive, false positive, true negative, and false negative. In all 4 cases, the possibilities of complications from the corresponding imaging strategies were discussed. In both true-positive and false-positive cases, complications from anticoagulation were also included. Patients with false-negative results were assumed to have BCVI but with insufficient treatment. They were consequently deemed to be at a higher risk of stroke.

1.2. Costs and outcomes

This analysis was conducted from a societal perspective. All costs, when available as Current Procedural Terminology codes, were taken as the 2014 Medicare Reimbursement value. In the remaining cases, literature values were used, after conversion to the 2014 purchasing power parity.

Outcomes were measured in quality-adjusted life years (QALY) over a 1-year horizon. A perfect health state would give a maximum of 1 and mortality would lead to 0. All complications were assumed to have full recovery with little reduction in QALY. A disutility factor of 3%–13% was deducted from the total expected utility for patients suffering from stroke as a result of BCVI [18].

1.3. Statistical analysis

Two primary indicators were used to determine if a strategy was cost effective; the incremental cost-effectiveness ratio

Table 2
Summary of literature review.

Author	Year	Total no. of pediatric traumatic patients	Risk factor criteria	No. of high risk patients	Screening modality	No. of patients scanned	No. of BCVI	No. of BCVI possessing risk factors	No. of stroke	No. of death caused by BCVI
Lew et al. [3]	1999	57,659	Not specified	Not specified	Not specified	Not specified	15 with CAIs	Not specified	6 strokes	1 from BCVI and 1 likely attributed by other injuries
Rozycki et al. [14]	2002	85	Seat belt sign	16	Arch aortography and DSA or CTA	16	0	0	0	0
Corneille et al. [15]	2011	8247	Not specified	Not specified	Not specified	Not specified	8 CAIs	Not specified	1 stroke	1 from internal carotid artery injury
Kopelman et al. [10]	2011	1209	Denver	128, but only 52 screened	49 by CTA, 1 by DSA, and 2 by both DSA and CTA	52	11	8	3 out of 8 patients not treated by anticoagulation and 0 in 2 patients treated by anticoagulation	0, 3 death caused by traumatic brain injury
Jones et al. [4]	2012	14,991	Denver	Not specified	31 by arteriography, 12 diagnosed by CTA, 2 exsanguinated	Not specified	45	36		3 exsanguinated from carotid injury
Azarakhsh et al. [16]	2013	5826	Memphis	538, but only 89 screened	64 by CTA, 39 by MRA, and 2 by DSA	89	23	20	2 out of 12 not treated by anticoagulation, and 0 out of 7 treated by anticoagulation	0, 3 caused by brain injury
Desai et al. [17]	2014	Not specified	Seat belt signs	42	CTA	463	8	0 had seat belt sign, 3 matched Denver c riteria	Not specified	0 caused by BCVI, 3 died from brain injury

CAIs, carotid artery injuries.