Impact of Continuous Evaluation of Technology and Therapy: 30 Years of Research Reduces Stroke and Mortality from Blunt Cerebrovascular Injury

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BACKGROUND: Blunt cerebrovascular injury (BCVI) was underdiagnosed until the 1990s when blunt carotid injuries were found to be more common than historically described. Technological advancements and regionalization of trauma care have resulted in increased screening and improved diagnosis of BCVI. The aim of this study was to demonstrate that systematic evaluation of the screening and diagnosis of BCVI, combined with early and aggressive treatment, have led to reductions in BCVI-related stroke and mortality.

STUDY DESIGN: Patients with BCVI from 1985 to 2015 were identified and stratified by age, sex, and Injury Severity Score. BCVI-related stroke and mortality rates were then calculated and compared. Patients were divided into 5 eras based on changes in technology, screening, or treatment algorithms at our institution.

RESULTS: Five hundred and sixty-four patients were diagnosed with BCVI: 508 carotid artery and 267 vertebral artery injuries. Sixty-five percent of patients were male, mean age was 41 years, and mean Injury Severity Score was 27. Incidence of BCVI diagnosis increased from 0.33% to approximately 2% of all blunt trauma ($p < 0.001$) during the study period. Ninety (14%) patients suffered BCVI-related stroke, with the incidence of stroke significantly decreasing over time from 37% to 5% ($p < 0.001$). Twenty-eight (5%) patients died as a direct result of BCVI, and BCVI-related mortality also decreased significantly over time from 24% to 0% ($p < 0.001$).

CONCLUSIONS: Although increased screening has resulted in a higher incidence of injuries over time, BCVI-related stroke and mortality have decreased significantly. Continuous critical evaluation of evolving technology and diagnostic and treatment algorithms has contributed substantially to those improved outcomes. Appraisals of technological advances, preferably through prospective multi-institutional studies, should advance our understanding of these injuries and lead to even lower stroke rates. (J Am Coll Surg 2017;224:595−599. © 2016 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

Originally described in the late 19th century by Verneuil, blunt cerebrovascular injuries (BCVIs) pose a relatively uncommon but potentially devastating threat to victims of blunt trauma.[1] In the mid-20th century, these injuries were considered rare, with <100 cases reported in the literature before 1990.[2] During the last 30 years, however, regionalization of trauma care combined with advances in digital subtraction angiography (DSA) and CT angiography (CTA), has resulted in a tremendous increase in the recognition of BCVI. In addition, recognition of the stroke potential of vertebral artery injuries (previously ignored and underdiagnosed) has resulted in focused screening protocols that attempt to identify these injuries.[3] With increased screening, there has been a concomitant increase in the recognized incidence of BCVI. In fact, modern reports of BCVI suggest that the true incidence is 2% to 3% of all blunt trauma patients.[4-7]

After BCVI, the potential for either an ischemic or embolic stroke exists. In fact, before the development of diagnostic screening criteria, most injuries were

Disclosure Information: Nothing to disclose.

Presented at the Southern Surgical Association 128th Annual Meeting, Palm Beach, FL, December 2016.

Received December 12, 2016; Revised December 12, 2016; Accepted December 12, 2016.

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http://dx.doi.org/10.1016/j.jamcollsurg.2016.12.008
ISSN 1072-7515/16

Abbreviations and acronyms
BCVI = blunt cerebrovascular injury
CTA = computed tomography angiography
DSA = digital subtraction angiography

recognized only after symptoms developed, which, in turn, led to a workup that ultimately identified the arterial injury.[2,8,9] Not surprisingly, if left untreated, our experience has been that up to 40% of patients with BCVI will go on to suffer a stroke.[10] However, some reports have indicated an untreated stroke rate as high as 70%, and there is considerable variability in the stroke rate, depending on the vessel injured and the grade of the injury.[11]

Both technology and treatment have advanced remarkably in step with increasing recognition of BCVI. Several studies identified the importance of early diagnosis and treatment for the prevention of stroke.[10,12,13] In many institutions, technological advances have led to the adoption of CTA as the primary diagnostic modality for BCVI instead of DSA. However, we have shown that CTA remains inferior to DSA for diagnosis and continue to use it as a confirmatory test.[4,5,14-18] Treatment of BCVI has also evolved from operative to nonoperative with anticoagulation and selective use of endovascular interventions representing the mainstay of therapy.[2,7,8,10,17,19-21]

The aim of this study is to demonstrate our institutional experience and the use of continuous evaluation of technology and treatment strategies, and the impact of those evaluations on outcomes after BCVI. We believe that the critical evaluation of emerging technology and therapy has led to substantial decreases in both BCVI-related stroke and mortality, and balanced resource use with the risk of missed injuries and anticoagulation in multiply injured trauma patients.

METHODS

Patients with BCVI during a 30-year period starting in 1985 were identified from hospital records and the trauma registry at the Elvis Presley Regional Trauma Center in Memphis, TN. Demographics, injuries, and outcomes, including BCVI-related stroke and mortality were recorded.

Patients were then placed into 1 of 5 groups based on the era in which they were injured. These eras were based on changes in institutional screening and treatment algorithms or technological advances (Table 1). The first era (1985 to 1995) consisted of patients who had a BCVI diagnosed by angiography, which was typically performed only after neurologic symptoms had developed. During this time period, there was no defined screening criteria for BCVI.[10] From 1996 to 2005, a specific set of injuries (Table 2) that had been shown to correlate with the presence of BCVI was used as a trigger for screening angiography.[22] During the next era (2006 to 2009), any patient with an indication (mechanism of injury, loss of consciousness, physical examination findings) for either a head and/or cervical spine CT also underwent screening CTA using 32-channel multi-detector technology. It was during this time period that any abnormality identified on CTA was added to the list of specific injuries to trigger a screening angiogram.[7] In mid-2009, the CT technology was upgraded to 64-channel multi-detector machines, which led to a significant increase in sensitivity (68%) and negative predictive value (97.5%).[4] The study during the fourth era (2010 to 2012) led to a substantial institutional screening algorithm change, where CTA became the primary screening test for BCVI, with DSA was reserved for those patients with a positive screening CTA or a negative screening CTA, but an unexplained neurologic deficit. The patients studied in the fifth era (2013 to 2015) were all diagnosed with the most recent screening algorithm, and monitoring of outcomes in these patients allowed us to validate the earlier change in our algorithm and ensure there were no strokes resulting from missed injuries.

Statistical analysis was performed using SAS software, version 9.4 (SAS Institute). Analysis of variance and chi-square tests were used to determine demographic differences between the patients in each era. A Cochran-Armitage test for trend was used to determine the significance of the changes in mortality and stroke over time.

Table 1. Eras of Research

Era	Years
I	1985 to 1995
II	1996 to 2005
III	2006 to 2009
IV	2010 to 2012
V	2013 to 2015

Table 2. Triggers for Digital Subtraction Angiography

Trigger
Le Fort II and III fractures
Skull base fracture
Cervical spine fracture
Seatbelt mark
Horner's syndrome
Unexplained neurologic deficit