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Utility of CT angiography in screening for traumatic cerebrovascular injury

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ABSTRACT

Objective: Computed tomographic angiography (CTA) is increasingly utilized to evaluate for traumatic cerebrovascular injury (TCVI). The purpose of this study was to determine the yield, management effect, and risk of stroke or poor outcome of a positive CTA in a large cohort of trauma patients.

Patients and Methods: A retrospective analysis was performed on 1290 consecutive trauma patients that underwent head and/or neck CTA at our level I trauma center from 2006 to 2015. Clinical variables assessed include mechanism of injury, neurological status, CTA findings, subsequent imaging results, patient management, and clinical outcomes.

Results: Among 1290 patients who underwent CTA, 200 (15.5%) were positive for TCVI, higher in blunt than penetrating trauma patients. In a generalized linear model, factors that increased likelihood of positive CTA included multiple cervical fractures, fractures with foraminal involvement, gunshot injury, Glasgow Coma Scale $\leq$ 13, and focal neurological deficit. Excluding cases with these factors lowered the positive rate to 4.3%. Of the 200 CTA-positives, 99 were treated for TCVI and 9 (4.5%) developed a subsequent stroke as compared to 5 (0.5%) in CTA-negative patients (odds ratio 10.2, Fisher exact test, $p < 0.001$). Risk of death or nursing facility discharge location was also higher in CTA-positive patients, correcting for age and presenting GCS ($p < 0.01$).

Conclusion: CTA had a modest yield in identifying TCVI in this cohort. When positive, CTA influenced management and predicted an increased risk of subsequent stroke and poor outcome.

1. Introduction

Traumatic cerebrovascular injury (TCVI) is reported to occur in approximately 15–25% of penetrating injuries to the neck and in up to 2.7% of blunt trauma to the head and neck [1,2]. Though not yet proven in a prospective trial, retrospective analyses suggest that early identification of TCVI may be important to lower the risk of subsequent infarction [3]. Patients who develop infarction typically have a latent period of 10–72 h [4,5]. Treatment during this latent period with both antiplatelet and antithrombotic therapy has been suggested to decrease the likelihood of injury-related infarct [6]. Whereas the decision to screen blunt trauma patients is most commonly based on criteria such as the modified Denver criteria, the decision to screen penetrating trauma is based on the location and trajectory of injury [7,8].

Advances in multi-detector computed tomographic angiography (CTA) have led to its acceptance as a screening tool for TCVI in both blunt and penetrating trauma. Compared to the reference standard of digital subtraction angiography (DSA), the diagnostic accuracy of CTA varies widely across studies, with sensitivities ranging from 52 to 68% [9,10]. CTA is, however, fast, non-invasive and more widely available, which has resulted in its wide adoption as the initial imaging strategy in screening for TCVI [4,7].

The frequency of CTA use for TCVI screening has increased considerably over the past decade [11]. At our institution it has approximately doubled when comparing 2006–2010 to 2010–2015, despite a steady rate of non-contrast head CT use for the same indications. Screening criteria have been developed for both penetrating and blunt trauma patients, but only a minority of patients are found to have TCVI despite these criteria, raising the possibility that the criteria are currently too broad [8,12]. On the other hand, TCVI has been reported in trauma patients that do not meet the standard criteria [7,13,14].

In this context, we performed this study to determine whether the widespread use of CTA to screen for TCVI remains warranted. Specifically, we sought to determine the frequency with which CTA was positive, affected management, and predicted the risk of subsequent stroke or poor outcome in a large cohort of consecutive patients undergoing CTA for screening of TCVI.

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2. Materials & methods

This study was approved by our Institutional Review Board. Given that this is a retrospective study, the requirement for informed consent was waived. We utilized a searchable electronic medical record database (Clinical Investigation Data Exploration Repository, CIDER) maintained by our university's Center for Biomedical Informatics to identify 1290 consecutive blunt and penetrating adult and pediatric trauma patients who underwent CTA of the neck or head and neck at our level I trauma center between January 2006 and June 2015 [15].

CTA examinations for TCVI screening at our institution typically include the head and neck. Images are acquired in the arterial phase with a bolus tracking method, and studies are interpreted using source images in conjunction with maximum intensity projections in the axial, coronal, and sagittal planes. The vast majority of CTA examinations were performed on either a SOMATOM Definition FLASH 128 row dual source CT scanner or a Sensation Open 40 CT scanner (both Siemens, Germany). CTA protocol parameters varied slightly over the years, but typically included a collimation of 128 × 0.6 mm (for the 128-detector scanner) or 40 × 0.6 mm (for the 40-detector scanner) with a 120 kV and Siemens Care Dose4D. The images were interpreted by radiology residents and/or neuroradiology fellows and final interpretations were provided by board-certified or board-eligible attending neuroradiologists.

The electronic medical record was reviewed for each of the 1290 patients for the following information: patient age; mechanism(s) of injury; site(s) and type(s) of injuries to the head and neck; presenting Glasgow Coma Scale; presenting focal neurological symptoms; recorded justification for CTA; CTA findings; vascular injury location; imaging findings from subsequent CT, MRI, and/or DSA; treatment for TCVI if present; subsequent stroke; and discharge location or expiration. Blunt TCVI was graded according to the Biffl scale [16]. The data set was subsequently wrangled, including grouping results into discrete categories, prior to subsequent analysis.

A key question in this study is whether screening CTA had sufficiently high yield for TCVI across the entire cohort and if presenting features could be identified that predicted the CTA result. In order to answer this question, we performed a generalized linear regression to identify predictive features (thresholded at $p < 0.05$) which then informed a scoring system to identify a subgroup of patients with the lowest yield. We also used the patient rule induction method (PRIM) to detect and identify sizable subgroup(s) (> 3% of the cohort) with a very low yield of positive CTA (< 3%) [17]. Descriptive statistics were obtained to evaluate the effect of a positive CTA on management and outcomes, and differences in proportions were examined using the Fisher exact test, with statistical assessment adjusted for multiple comparisons using the Bonferoni method. All statistical analyses were performed in R (version 3.1.1).

3. Results

3.1. Yield of CTA for TCVI

Presenting characteristics of the 1290 patients are shown in Table 1. CTA was positive in 49/437 (11.2%) patients presenting with penetrating trauma and 152/862 (17.6%) patients presenting with blunt trauma, with overall 200 (15.5%) positive CTAs for TCVI (note that 1 positive CTA occurred in a patient with both penetrating and blunt trauma). CTA was more often positive in blunt trauma patients as compared to penetrating trauma patients (odds ratio (OR) 2.6 for blunt vs penetrating trauma, 95% CI 1.8–3.7, $p < 0.0001$).

Based on a general linear model, several presenting factors were predictive of a positive CTA. These factors included multiple cervical fractures and/or subluxation ($p < 0.01$), cervical fracture with involvement of the transverse foramen or carotid canal ($p < 0.0002$), gunshot injury ($p < 0.0001$), Glasgow Coma Scale < 13 ($p < 0.02$), and focal neurological deficit prior to CTA ($p < 0.003$). Excluding patients with any of these factors lowers the positive CTA rate to 4.3% (17/394); 16 (6.9%) in 232 patients with blunt trauma, and 1 (0.6%) in 170 patients with penetrating trauma. Conversely, patients with 1, 2, or > 2 of the risk factors had a 16.5% (107/649), 27.6% (62/225), and 63.6% (14/22) CTA positivity rate, respectively (Fig. 1). The one penetrating trauma patient with 0 risk factors who had a positive CTA was treated with heparin until a follow-up carotid ultrasound examination was found to be negative; this patient was later discharged home without a neurological deficit.

We further used PRIM to determine whether there existed another sizeable subgroup in whom the yield of CTA was < 3%. In addition to penetrating trauma patients with 0 risk factors, the largest subgroups with low CTA yield included 65/1290 patients (5.0%) who had isolated facial soft tissue injury or brain injury (i.e., no fracture) and no reported focal neurological symptoms, and another 41/1290 patients (3.2%) above the age of 80 typically presenting after a fall, with no focal neurological symptoms nor any fracture involving a foramen or the carotid canal. In each subgroup only 1 CTA was positive, and both were interestingly found to be false-positives based on subsequent DSA.

3.2. Effect of CTA on management and risk for stroke

Of the 200 CTA positive patients, 99 (49.5%) were treated with either antiplatelet therapy or anticoagulation, 11 of whom also underwent endovascular intervention (Table 1). The rate of subsequent stroke in patients with a positive CTA was 4.5% (9 out of 200 patients) as compared to 0.5% in the CTA negative patients (5 out of 1090 patients) (OR 10.2, 95% CI 3.0–39.2, Fisher exact test, $p < 0.001$). This relationship persisted when controlling for age, injury type, and GCS and focal neurological symptoms at presentation ($p < 0.001$). The 9 CTA positive patients with subsequent stroke had a variety of ages (17–94 years), injury mechanisms (gunshot wounds, motor vehicle collisions, fall and strangulation), TCVI injury grades (blunt only: 5 grade II, 1 grade III, and 1 grade IV), and management (3 endovascular, 4 antithrombotic alone, and 2 no treatment).

Compared to those with a negative CTA, patients with a positive CTA were more likely to expire (OR 2.4, 95% CI 1.3–4.5, Fisher exact test: $p = 0.02$, Bonferonni corrected) or be discharged to a nursing facility (OR 2.1, 1.2–3.8, $p = 0.05$), and less likely to be discharged home (OR 0.4, 0.3–0.6, $p < 0.001$). When correcting for age and presenting GCS, a positive CTA remained predictive of increased likelihood to expire or be discharged to a nursing facility ($p < 0.01$).

4. Discussion

Despite the rapid increase in CTA use for TCVI screening, our results suggest that the overall yield of CTA remains reasonable in both blunt and penetrating trauma patients. Efforts to identify a subgroup in whom CTA was virtually always negative included a subgroup of 170/1290 (13.2%) non-gunshot penetrating injury patients who presented with a high GCS, had no focal neurological symptoms and no significant fractures of the cervical spine, transverse foramina, or carotid canal. Beyond this, only two small subgroups each comprising 5% or less of the entire cohort could be identified. Overall, these results suggest that for the vast majority of patients in this cohort, performing CTA to screen for TCVI was not futile and had modest yield.

When the CTA was positive, approximately half of the patients were actively managed for TCVI. Impressively, a positive CTA indicated an approximately 10-fold higher risk of subsequent stroke, even after accounting for other clinical factors. A positive CTA also predicted a higher risk of subsequent death or discharge to a nursing facility independent of age or presenting GCS. These findings confirm that a positive CTA is clinically and prognostically significant.

The optimal management of patients with TCVI remains to be determined as no prospective randomized clinical trials have yet been