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Screening and detection of blunt vertebral artery injury in patients with upper cervical fractures: The role of cervical CT and CT angiography

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ABSTRACT

Objective: To evaluate the clinical utility of nonenhanced CT (NECT)-based screening criteria and CTA in detection of blunt vertebral artery injury (BVAI) in trauma patients with C1 and/or C2 fractures.
Methods: We retrospectively reviewed the clinical records of all blunt trauma patients with C1 and/or C2 fractures between 8/2006 and 9/2011. Cervical CTA was prompted by cervical fractures involving/adjacent to a transverse foramen, and/or subluxation on NECT. Two neuroradiologists independently reviewed the CTA studies, and graded the BVAI.
Results: 210 patients were included; of these, 124 underwent CTA (21/124 with digital subtraction angiography, DSA), and 2 underwent DSA only. Overall, 30/126 suffered BVAI. Among 21 patients who underwent both CTA and DSA, there was 1 false negative and 1 false positive (both grade 1). There was strong interobserver agreement regarding CTA-based BVAI detection (kappa = 0.93, $p < 0.001$) and grading (kappa = 0.90, $p < 0001$). Only 3/30 BVAI patients suffered a posterior circulation stroke; none of the patients who had a negative CTA or were not selected for CTA, based on NECT screening criteria, suffered symptomatic stroke. While C1/C2 comminuted fracture was more common in patients with high grade BVAI ($p = 0.039$), simultaneous C3–C7 comminuted fracture increased the overall BVAI risk ($p = 0.011$).
Conclusion: CTA reliably detects symptomatic BVAI in patients with upper cervical fractures. Utilization of NECT-based screening criteria such as transverse foraminal involvement or subluxation may be adequate in deciding whether to perform CTA, as no patients who were not selected for CTA suffered a symptomatic stroke. However, CTA may miss lower grade, asymptomatic BVAI.

1. Introduction

The incidence of blunt cerebrovascular injury (BCVI) is approximately 1–2% of all blunt traumas [1]. Timely diagnosis of BCVI is crucial due to subsequent neurologic sequelae that may require long-term rehabilitation and prolonged hospitalization [2]. Indeed, blunt vertebral artery injury (BVAI) may be associated with a 14–24% stroke rate, which is markedly reduced with early anticoagulation/antithrombotic therapy, underscoring the importance of early diagnosis [3–5]. In this regard, it has been shown that certain cervical injury patterns have a higher risk of developing BVAI, such as cervical subluxation and transverse foraminal fracture [6].

Traditionally, digital subtraction angiography (DSA) has been considered the "gold standard" for identifying BCVI [7]. Although DSA has a complication rate of <2%, the procedure is invasive with various potential complications. On the other hand, CTA is noninvasive, and has become a routine screening tool for BCVI. A major advantage of utilizing screening CTA in the emergent setting (relative to DSA) is the reduced time to diagnosis of BCVI by nearly twelve-fold, which may reduce the stroke rate by up to fourfold [8]. As compared to DSA, Eastman et al. have demonstrated a 98% rate of concordance between DSA and the 16-slice scanner CTA in the detection of BCVI; that study and others have shown that CTA occasionally misses lower grade injuries (typically Grade 1), where >90% of grade 1 injuries spontaneously resolve without therapy or symptoms [5,9,10]. However, this detection rate has not been reported with a focus on *upper cervical* injuries.

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The limited, available literature from prior studies have demonstrated an association of BVAI's with upper cervical fractures, particularly with the presence of transverse foraminal involvement or subluxation [6,11]. However, this subject has barely been revisited after the emergence of CTA, necessitating a refocusing on this subject with regards to the newer multidetector scanners (i.e. ≥16 slices per gantry rotation). As the greatest degree and range of motion in the cervical spine exists at the C1 and C2 levels, and since the vertebral arteries typically have a curved course at C1–2, the vertebral arteries that traverse these levels could potentially have an inherent susceptibility to blunt injury.

In our hospital, the visualization of cervical spine subluxations and/or fractures involving the transverse foramen on screening nonenhanced CT (NECT) have been used as criteria to perform CTA screening for BVAI, based on studies demonstrating that the vast majority of BVAI's are associated with either cervical spine subluxations or transverse foraminal fractures [1,6,11]. Thus, the current study was designed to retrospectively evaluate the effectiveness of our screening protocol (i.e. NECT screening for patients to undergo CTA) in detecting *clinically symptomatic* BVAI in patients with C1 and/or C2 fractures, by performing a review of the medical records and of the CTA's over a 5 year period. In the patient subset undergoing DSA, we also set out to particularly evaluate if CTA misses lower grade BVAI in *upper cervical injuries*, akin to the data previously reported in studies of CTA of the *entire cervical* region. A third goal was to determine if any concomitant fracture patterns, subluxations, or anatomic variations (e.g. hypoplastic vertebral artery) were associated with a higher risk of developing BVAI in patients with C1–2 fractures.

2. Materials and methods

2.1. Patients

This study was performed at a Level I regional trauma center. After institutional review board approval, we retrospectively reviewed the medical records and imaging findings in all patients who underwent cervical spine NECT for blunt injury from July 2006 to September 2011. A previously described combined neurosurgery–neurology–neuroradiology protocol at our hospital determines whether the patients should be evaluated with cervical spine NECT [10]. We included all blunt trauma patients with C1 and/or C2 fracture on cervical spine NECT who were older than 16 years at the time of admission. The following characteristics were tabulated in all patients: the mechanism of injury, the indication/symptom leading to CT, the level of cervical fracture, the presence of transverse foramen fracture at C1 and/or C2 versus C3–C7, the presence of comminuted fractures at C1–2 or at C3–7, the presence of >2 mm subluxation at C1–2 or C3–7 level, and the presence of occipital condyle fracture. The presence of vertebral artery hypoplasia was also determined in those who underwent CTA and/or DSA. The medical records were reviewed for all study patients, recording the time to clinical followup, outcome, and treatment, with the outcome determined based on the discharge and clinic follow up notes.

2.2. Screening protocol

As per our multidisciplinary trauma protocol, all patients with suspected vertebral injury during above mentioned time period were evaluated immediately by a 64-channel multidetector CT scanner, which is located in the emergency department. The decision to proceed with cervical spine NECT is based on clinical findings in the stabilization room, as described previously, based on modified Denver screening criteria [10]. Our protocol also initiates for CTA to evaluate patients with transverse foraminal fractures, or vertebral subluxations of >2 mm [10]. A subset of patients may proceed to catheter DSA if there is either uncertainty in the CTA diagnosis, if there is rapid cervical swelling, or if a vascular intervention seems likely (even without CTA).

2.3. Imaging acquisition protocol

The cervical spine NECT's were obtained on a 64-slice multidetector scanner (*Brilliance CT; Philips Medical Systems, Best, Netherlands*), *with* a spiral acquisition obtained from T2 up to the skull base at 1.0 mm collimation, 300 mAs, 140 kV, and reconstructed in the axial, sagittal, and coronal planes. For CTA, 80 cc of intravenous contrast (*Iohexol 350 [Omnipaque]; GE Healthcare Ireland, Cork, Ireland*) was injected at a rate of 4 mL/s, via an 18–20 gauge antecubital line with "triggering" off at the aortic arch (140 HU threshold). Scan parameters included 120 kV, 300 mAs, and 0.67 mm collimation. All CTA images were sent to a VITREA postprocessing workstation (*Vital Images, Minnetonka, MN*). The reviewed images typically consisted of, at least, reconstructed images at 0.9 mm thickness in the axial, coronal, and sagittal planes, as well as 3D volume-rendered reconstructions. The neuroradiologists were also free to manipulate the images in a near-infinite number of projections, if deemed necessary.

Catheter DSA, when performed, utilized a biplane unit *(Integris Allura, Philips, Best, Netherlands*); after preliminary arch aortography, selective bilateral vertebral angiography was performed in multiple planes, with runs in at least 3 planes (AP, lateral, and at least one oblique plane) to evaluate both vertebral arteries, using a technique described previously [10,12]. In some patients, carotid arteriography was also performed based on the presence of other fractures.

2.4. Image review

For the purpose of the image review, two staff neuroradiologists, with >5 years' experience (AMM and CSP) in interpreting cervical CTA, graded the CTA's (and DSA's, if performed), using a commonly accepted grading system of blunt cerebrovascular injury (grade 0–5): Grade 1: vessel wall irregularity or dissection with <25% stenosis; Grade 2: dissection or intramural hematoma with >25% stenosis; Grade 3: pseudoaneurysm; Grade 4: vessel occlusion; Grade 5: transection with extravasation [6]. The source axial CTA images, multiplanar reformats, and 3D reconstructions were independently reviewed on a 3D workstation, with the reviewers blinded to the DSA findings (if performed). Consensus grading was only performed by both reviewers at the same sitting if there was an interobserver discrepancy. The reviewers were also blinded to the initial neuroradiology interpretation (i.e. the finalized report), and they were also blinded to the clinical data and followup.

2.5. Statistical analysis

Interobserver agreement was calculated using Cohen's kappa. Dichotomous variables were compared using chi-square or Fisher's exact tests. Stepwise multivariate binary logistic regression was used to determine the independent predictor(s) of BVAI, including the presence of: transverse foramen fracture, comminuted fractures, >2 mm subluxation (and whether at the C1–2 level versus at the C3–7 level), occipital condyle fracture, and vertebral artery hypoplasia. SPSS v20 for Windows (*SPSS, Chicago, IL*) was utilized for all statistical analyses. The level of significance was chosen to be $p < 0.05$.