Multidetector CTA for Diagnosing Blunt Cerebrovascular Injuries

4th Nordic Trauma Course 2006

Stuart E. Mirvis, M.D., FACR
Department of Diagnostic Radiology and Nuclear Medicine,
University of Maryland School of Medicine

Cerebrovascular Injuries from Blunt Trauma

- What is the incidence historically?
- How is CT-A performed to screen the neck vessels -- the total body survey?
- How do you classify injuries by CT-A?
- How does “screening” influence “diagnostic yield”?
- How do we treat these injuries?
- Do we need to follow these injuries?
- Can early CT-A diagnosis by screening influence the outcome?
Incidence

- Uncommon in the general blunt trauma population
  - BCI: 0.14 - 1.1%
  - BVI: 0.4 - 0.53%
- High-risk patients
  - BCVI: 29 - 44%

Stroke related mortality

- BCI: Mortality: 23 - 28%
  - 48% to 58% of survivors having permanent severe neurologic deficits
- BVI: Mortality: 0 - 8%
  - Stroke up to 24%
- Treatment*:
  - BCI: 6-11%
  - BVI: 0%

*Miller et al. (J Trauma, 2001); Miller et al. (Ann Surg, 2002); Biffl et al. (Ann Surg, 2000)
**High-risk criteria for BCVI - 1**

- C-spine fracture
  - involves transverse foramen
  - 30% or more subluxation
  - marker rotation or distraction
- Basilar skull fracture – cavernous sinus
- Severe facial fracture
- Horner's syndrome
- Neck seat-belt mark

**High-risk criteria for BCVI - 2**

- Carotid & vertebral artery perivascular hematoma
- GCS < or = 6 @ 24 hr. post injury
- Neurologic exam not compatible with brain imaging
- Stroke or transient ischemia
- Hanging attempt with cervical hematoma or c-spine fracture
A retrospective experience: Vancouver General

- 31 BCVI in 22 patients (10-year review)
- Stroke rate 60%, mortality 25%
- Risk factors by multivariate analysis: facial injury, skull base fracture, neck injury, thoracic injury, abdominal injury, cervical spine injury all significant
- GCS ≤ 8, thorax injury adjusted injury severity thorax score > or = 3 highest significance


Blunt carotid and vertebral injury grading scale

<table>
<thead>
<tr>
<th>Injury grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Luminal irregularity or dissection with &lt;25% luminal narrowing</td>
</tr>
<tr>
<td>II</td>
<td>Dissection or intramural hematoma with ≥25% luminal narrowing, intraluminal thrombus, or raised intimal flap</td>
</tr>
<tr>
<td>III</td>
<td>Pseudoaneurysm</td>
</tr>
<tr>
<td>IV</td>
<td>Occlusion</td>
</tr>
<tr>
<td>V</td>
<td>Transection with free extravasation</td>
</tr>
</tbody>
</table>

Blunt Carotid and Vertebral Arterial Injuries: Prognosis

Biffi WL, et al

Table 1. Conditional probability of blunt carotid and vertebral arterial injuries based on multiple logistic regression analysis.

<table>
<thead>
<tr>
<th>Carotid arterial injury (Risk factors: GCS ≤ 6, petrous fracture, DAI, LeFort II or III fracture)</th>
<th>No risk factors</th>
<th>Any one risk factor</th>
<th>Any two risk factors</th>
<th>Any three risk factors</th>
<th>All four risk factors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20%</td>
<td>33–48%</td>
<td>56–74%</td>
<td>80–98%</td>
<td>95%</td>
</tr>
<tr>
<td>Vertebral arterial injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No cervical spine fracture</td>
<td>3%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cervical spine fracture</td>
<td>33%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

GCS: Glasgow Coma Score; DAI: diffuse axonal brain injury.

A total of 249 patients underwent arteriography; 85 (34%) had injuries.

<table>
<thead>
<tr>
<th>Worst injury grade</th>
<th>BCI Stroke (%)</th>
<th>BCI Mortality (%)</th>
<th>BVI Stroke (%)</th>
<th>BVI Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>3</td>
<td>11</td>
<td>19</td>
<td>31</td>
</tr>
<tr>
<td>II</td>
<td>11</td>
<td>11</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>III</td>
<td>33</td>
<td>11</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>IV</td>
<td>44</td>
<td>22</td>
<td>33</td>
<td>13</td>
</tr>
<tr>
<td>V</td>
<td>100</td>
<td>100</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

BCI: blunt carotid arterial injury; BVI: blunt vertebral arterial injury.
CT-A in Trauma

Left ICA dissection G2 – Horner’s

MDCT for vascular injury Grade 2
CT-A in Trauma

Grade 3: Lf. ICA injury

Grade 4 ICA
Grade 5: Precavernous ICA bleed: skull base fracture

Diagnosis

- 4-vessel catheter angiography
  - “Reference” standard
  - Labor intensive
  - Expensive
  - Invasive - some risk of injury
  - Time-consuming
  - ? Availability
CT-A in Trauma

Diagnosis

- CT-A
  - Quick to perform
  - Non-invasive
  - Usually available
  - Requires MDCT (16+ detectors)
  - Sensitivity, Specificity, Accuracy, PV ??

Single-slice Helical CT

- BCI:
  - Sensitivity: 47-68%
  - Specificity: 67-99%

- BVI:
  - Sensitivity: 53%
  - Specificity: 99%

Prospective Screening: Helical CT & MRA

- Screened all patients with risk factors 4-vessel angio.
- N=216 over 2-years (3.5% all admissions)
- Angiography diagnosed 24 pts with CAI and 43 pts with VAI (total = 29% of 216)
- CTA 47% sensitive vs. catheter angio (CAI); 53% (VAI)
  N= 143
- MRA 50% sensitive vs. catheter angio (CAI); 47% (VAI)
  N=143
- Rate with aggressive screening of 1.03% all blunt admissions


CTA for Blunt Cervical Vascular injury

- 468 patients screened with CTA (4-MDCT)
- 19 pts. had 24 BCVI
- 17 pts. asymptomatic at screening
- Sensitivity 100%, specificity 94%, prevalence 3.7%, PPV 37.5%, NPV 100% (negatives had no angiograms)
- CT is an excellent test to screen for BCVI

Sonography with Doppler

- Operator expertise dependent
- Readily available
- No access to intracranial circulation
- Limited by anterior bony thorax

Doppler US and CTA for blunt cerebrovascular injury

- Retrospective 5 yr. review
- US vs. CTA screening periods
- Early cohort 1471 pts.; late cohort 407 pts.
- US found 5 injuries, missed 8 (led to cerebral ischemia); frequency of 0.9%; sensitivity of 38.5% and specificity 100%
- CTA found 11 injuries for 2.7% rate with 100% sensitivity and one false positive
- US has inadequate sensitivity

CT-A in Trauma

CT-A (helical) and MRA vs. Cerebral Angiography

- 5-year study blunt cerebrovascular injury (prospective vs. retrospective)
- Screened: Horner’s, skull base fx. F. lacerum., LeFort II/III, soft tissue neck injury, neurologic abn. unexplained by intracranial study
- 4-vessel angiogram
- 216 pts. screened in 2 years (3.5% all admissions)
- 24 BCI injuries and 43 BVI on angiograms
- 29% positive among screened pts.
- BCI incidence the same, BVI incidence increased
- BCI stroke rate the same, BVI stroke rate decreased
- In 143 pts. CTA 47% sensitive, MRA 50% sensitive (carotid)
- CTA 53% sensitive and MRA 47% sensitive (vertebral)


What about screening all patients with blunt trauma with or without risk factors?

How will that effect diagnosis and ultimate outcome?
The "Shan Scan"
- 1st - dry head CT
- Arms over head: 120-150ml IV contrast-bolus timing
- IV enhanced total body scan in one sweep from circle of Willis through pubic symphysis
- 16-detectors (0.75 mm profile) (1.5mm for large patient)
- Reconstruct all axials at 3-5 mm
- For MPR, MIP, volume use 1 mm slices
Screening algorithm for BCVI – No risk factors

Risk factor negative

Whole body protocol

Done

Risk factor positive

Targeted CT neck

Equivocal

Elective Angiogram

Negative

Positive

Flow-limiting, no anticoagulation, stent possible

Occluded

Not flow-limiting & can anticoagulate, no stent possible

Emergent 4-vessel arteriogram - stent

Proximal coils?, Anti-coag. if possible

CT-A F/U
Left ICA stab wound

Bilateral ICA Injury
Assault with ax: bilat. ICA Grade 2

Bilateral ICA dissection
Rt. ICA pseudoaneurysm: G3

Grade 2 left ICA
43 patients had cerebral angiography within 7 days after blunt cranial trauma over a 5 yr.--17 unilateral and 26 bilateral carotid angiography.

21 carotid canal fractures in 17 patients with 11 ICA injuries in 10 patients. Six with ICA injury also had a carotid canal fracture.

Carotid canal fracture: sensitivity of 60% and specificity of 67% for detection of ICA injury.

Petrous carotid injury: skull base fracture

Cavernous Carotid: skull base fracture
CT-A in Trauma

C-C fistula (skull base fracture)

C – C fistula with facial smash
Occluded Rt. ICA

Delayed embolization
### Injury Progression – with anticoagulation

<table>
<thead>
<tr>
<th>Day #1</th>
<th>Day #12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 2 ICA injury.</td>
<td>Grade 3 ICA injury and Grade 3 vertebral artery injury (PsAn)</td>
</tr>
</tbody>
</table>

**Images:**
- Grade 2: July 2005
- Grade 3 October 2005
- Post-stent
Progression of pseudoaneurysm – 1 month
Rapid resolution of CCA intimal flap

Traumatic Vertebral Artery Injuries

- Far more common than thought before CT-A, MRI era
- In patients with fracture-dislocations incidence is (17-42%)
- Mechanism: distractive flexion with vessel stretching
- Consider with major displacements (UID, BID, flexion teardrop or f. transversarium fractures)
- Thrombosis most common outcome
- Vertebrobasilar symptoms rare if unilateral
- Injury in segment 2 (C6 to C0) most common
- May recanalize over time (about 25% @ 3 months in 1 study)

Blunt Trauma Vertebral Artery Injury

- 4-vessel angiography in 605 patients (290 c-spine fractures)
- 92 had VA injuries
- 71 (77%) of the 92 had c-spine fractures
- 18 (25%) of 71 had bilateral VA injury
- 9 (13%) of 71 had a CA injury

Unilateral facet dislocation: Left vertebral artery occlusion

C-spine fx. C1 with basilar artery occlusion
Rt. vertebral pseudoaneurysm

Bilateral vertebral artery G2
### MDCT – 16 Versus Angiography
**UMMC/Shock-Trauma**

- Angiography performed in 45 patients (high-risk or + CTA -16)
- Angio: BCI = 27, BVI = 17 (11 multiple vessels)
- 56 MDCT (11 also dedicated CTA) neck in 45 pts.
- MDCT-A for BCI was 82% sensitive, 76% specific, 72% PPV, 85% NPV for BCI (individual vessels)
- MDCT-A for BVI was 89% sensitive, 96% specific, 89% PPV, 96% NPV

*Sliker CW, et al. ASER 2005*

### Routine screening for blunt cerebrovascular injuries: Diagnostic accuracy of 16-slice MDCT

- Dec. 2004 – March 2006
- CT-A (16-MDCT) and cervical angiography within 48 hr.
- 108 subjects with 125 CT-A (49 prospective and 59 retrospective)
- Studied 524 carotid and 297 vertebral segments
- Angio confirmed 91 carotid and 43 vertebral segments positive
- CT-A was 59% sensitive, 96% specific, 90% accurate for carotid injury
- CT-A was 57% sensitive, 99% specific and 92% accurate for vertebral injury
- Negative or equivocal patients with high-risk clinically should undergo 4-vessel angiography

*Sliker CW, Shanmuganathan K, Mirvis SE. Abstract 2006 RSNA*
Routine screening cervical CT-A (16)

- University of Maryland Shock-Trauma
- Retrospective review (14 months)
- 403 patients
- 11 (2.7%)

Potential Prognostic Factors

- Number of cervical-cranial vessels injured
- Length of injury
- Can receive anticoagulation?
- Anatomy of injury - permits stenting?
- Collateral flow
- Progression or resolution of injury in follow-up
Treatments for BCVI – Controversial and Patient Dependent

- Anticoagulation – treatment of choice for dissection, intimal flap, thrombus
- Anti-platelet therapy (looks good but under investigation)
- Stent placement – no medium to long-term results, anatomy critical (not without complications)
- Coil embolization of thrombosed vessels?
- Direct surgical repair if accessible

F/U CTA essential: lesions get better and lesions get worse

Scary Situation – thrombus, but patent
Treatment Results for Blunt Carotid Artery Injury

- 7 yr. study
- 643 pts. had screening angiography based on risk factors
- 114 (18%) had CAI
- 73 had anticoagulation (heparin 54, antiplatelet 17, 2 LMW heparin)
- No CVA in anticoagulation group
- 41 had no anticoag. (contraindicated, symptoms before dx, coil / stent placement)
- 19 (46%) had neurologic ischemia (all who had symptoms prior to treatment or stent / coil placement)


Endovascular Stent for CAI

- Patients who have carotid stents placed for blunt carotid pseudoaneurysms have a 21% complication rate and a documented occlusion rate of 45%. (N = 23)
- There were no delayed neurologic or vascular complications, and no lesions recurred during the follow-up periods (mean 20.3 months). (N = 10)
- No strokes occurred after the placement of the stents. Mean follow-up period has been 2.5 years. (N =14)

3 different articles
Thanks for your attention!