Blunt Cerebrovascular Injury and Angiography

Janeen Jordan, PGY3
Grand Rounds
April 3, 2006
Epidemiology

- 1 – 2% of trauma admissions
- Rapid deceleration assoc with hyperflexion and rotation
- Intimal tears, dissection, psa, transection
  - Avf, ccsf, thrombus, emboli
- 20-40% of patients have bilateral injuries
- 13-15% of patients have both CAI and VAI
Mechanism

- 50% high speed MVC
- 11% Fall
- 10% Auto – ped
- 9% MCC
- 19% other: assault, ski/snowboard accidents, construction injuries
Denver screening criteria for BCVI

♦ Signs and symptoms of BCVI
  – Arterial hemorrhage
  – Cervical bruit
  – Expanding cervical hematoma
  – Focal neurologic deficit
  – Neurologic examination incongruous with head CAT scan findings
  – Stroke on secondary CAT scan

♦ Risk factors for BCVI
  – High-energy transfer mechanism with
    • LeFort II or III fracture
    • Cervical-spine fracture patterns: subluxation, fractures extending into the transverse foramen, fractures of C1–C3
  – Basilar skull fracture with carotid canal involvement
  – Diffuse axonal injury with GCS <6
  – Near hanging with anoxic brain injury
Pathophysiology

♦ Intimal injury incites plaque formation
♦ Thrombogenesis
♦ Resolution of the plaque, pseudoaneurysm formation, continued dissection and plaque thrombus
♦ stroke
# Table 1. Denver grading scale for blunt carotid artery injury

<table>
<thead>
<tr>
<th>Grade</th>
<th>Angiographic Findings</th>
<th>Prognosis</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Vessel wall irregularity or dissection with &lt;25% of luminal diameter</td>
<td>Good (7% progress)</td>
<td>Systemic anticoagulation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>controversial</td>
</tr>
<tr>
<td>II</td>
<td>Raised Intimal flap, thrombus, dissection, or hematomas &gt;25% of luminal diameter</td>
<td>Fair with treatment (70% progress)</td>
<td>Systemic anticoagulation</td>
</tr>
<tr>
<td>III</td>
<td>Pseudoaneurysms</td>
<td>Require intervention</td>
<td>Surgery or stenting</td>
</tr>
<tr>
<td>IV</td>
<td>Total vessel occlusion</td>
<td>Outcome usually assured at time of diagnosis</td>
<td>Systemic anticoagulation</td>
</tr>
<tr>
<td>V</td>
<td>Transection</td>
<td>Very poor, high mortality</td>
<td>Surgery</td>
</tr>
</tbody>
</table>
Average Age
- 35 – 38yrs (67% male)

Average time to sx onset
- 12 – 72hours (30% symptomatic)

Average time to diagnosis
- 18 – 53hrs

9% grade I injuries progress to higher grade

43% grade II injuries progress
Morbidity & Mortality

♦ Overall mortality
  – 21 – 31%

♦ Morbidity
  – 37 – 58% have permanent neurologic disability
Benefit of early diagnosis and treatment

♦ Fabian et al
  – Significant reduction in morbidity and mortality with heparin therapy

♦ Cothren et al
  – Untreated pt – 21% stroke rate
  – CAI increase by grade
  – VAI ~20% stroke
### Table 3. Estimated stroke rate if asymptomatic patients had not been treated with antithrombotics agents Injury type and grade

<table>
<thead>
<tr>
<th>Injury type and grade</th>
<th>No. of injuries</th>
<th>Stroke rate by grade</th>
<th>Est pt with stroke</th>
<th>Overall no. of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CAI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>41</td>
<td>3%</td>
<td>1.23</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>12</td>
<td>14%</td>
<td>1.68</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>33</td>
<td>26%</td>
<td>8.58</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>3</td>
<td>50%</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>0</td>
<td>100%</td>
<td>0</td>
<td>12.99</td>
</tr>
<tr>
<td><strong>VAI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>40</td>
<td>6%</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>12</td>
<td>38%</td>
<td>4.56</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>17</td>
<td>27%</td>
<td>4.59</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>28</td>
<td>28%</td>
<td>7.87</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>0</td>
<td>100%</td>
<td>0</td>
<td>19.42</td>
</tr>
</tbody>
</table>
Diagnosis

♦ Arteriography
  – Invasive
  – Resource intensive ($6800)
  – Complications
    • Catheter insertion site injuries (1-2% hematomas, PSA formation)
    • Contrast administration (1-2% renal dysfunction, allergic reaction)
    • Stroke (less than 1%)
Angiogram vs CT angiography and MRA

♦ Miller et al
♦ Univ Tenn, Memphis
♦ Prospective analysis, 2002
♦ Screened 216 pts over 2 yrs
  – (Jan 2000 – Mar 2002)
  – Angiogram
  – CTA
  – MRI
Screening Triggers for suspected blunt Cerebrovascular injury

Cervical Spine fracture

Neurologic exam not explained by brain imaging

Horner’s Syndrome

LeFort II or III facial fractures

Skull base fractures involving the foramen lacerum

Neck soft tissue injury (e.g., seatbelt injury or hanging)
Methods:

♦ Angiography with DSA
  – Hemostasis with VasoSeal

♦ CTA
  – Single contrast bolus 125mL at 3mL/s
  – Helical 1mm images from Ao Arch to skull base
  – Every 3rd image printed for review
  – Sagittal and coronal recons

♦ MRA
  – 2D images without contrast 0.2 Tesla magnet
  – Ao Arch to skull base

♦ Reads done by Staff Radiologists blinded to study
Results:

♦ 216pt screened (212 with 1 screening criteria)
♦ 63pt with BCVI (29%); 1.03% incidence
♦ Avg time to diagnosis 29.8hrs
♦ CVA
  – 50% CCF (1/2)
  – 100% occlusions (3/3)
  – 23% dissections (5/22)
♦ 79% diagnosed prior to sx

<table>
<thead>
<tr>
<th></th>
<th>CAI (n=27)</th>
<th>VAI (n=49)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissection</td>
<td>22(82%)</td>
<td>27(55%)</td>
</tr>
<tr>
<td>Occlusion</td>
<td>3(11%)</td>
<td>22(45%)</td>
</tr>
<tr>
<td>Carotid/cavernous fistula</td>
<td>2(7%)</td>
<td>-</td>
</tr>
</tbody>
</table>
Results:

♦ 143pt Angio and CTA
  – 17:8 CAI    (47%)
  – 30:16 VAI   (53%)
  – 1 false positive

♦ 21pt MRA
  – 4:2 CAI     (50%)
  – 17:8 VAI    (47%)
  – 1 false positive
### Results: Sensitivity and Specificity

<table>
<thead>
<tr>
<th>Method</th>
<th>CTA</th>
<th>CAI</th>
<th>VAI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sensitivity</td>
<td>47%</td>
<td>53%</td>
</tr>
<tr>
<td></td>
<td>Specificity</td>
<td>99%</td>
<td>99%</td>
</tr>
<tr>
<td>MRA</td>
<td>Sensitivity</td>
<td>50%</td>
<td>47%</td>
</tr>
<tr>
<td></td>
<td>Specificity</td>
<td>100%</td>
<td>97%</td>
</tr>
</tbody>
</table>

**Conclusion:** CTA/MRA currently inadequate screening tools

Angiogram vs CT Angiography and MRA

♦ Biffl, Moore, Johnson, Burch, Mestek, Ray
♦ Denver Health
♦ Prospective analysis, 2002
♦ 46pts underwent CTA and angio
♦ 16pts underwent MRI and angio
Table 1 Results of Computed Tomographic Angiography Compared with Arteriography

<table>
<thead>
<tr>
<th>ART Positive</th>
<th>ART Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTA positive</td>
<td>15</td>
</tr>
<tr>
<td>CTA negative</td>
<td>7</td>
</tr>
</tbody>
</table>

ART, arteriography; CTA, computed tomographic angiography.

Table 2 Accuracy of Computed Tomographic Angiography by Injury Grade

<table>
<thead>
<tr>
<th>Injury Grade</th>
<th>ART Diagnosed</th>
<th>CTA Diagnosed (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>11</td>
<td>5 (45)</td>
</tr>
<tr>
<td>II</td>
<td>7</td>
<td>6 (86)</td>
</tr>
<tr>
<td>III</td>
<td>8</td>
<td>7 (88)</td>
</tr>
<tr>
<td>IV</td>
<td>1</td>
<td>1 (100)</td>
</tr>
</tbody>
</table>

ART, arteriography; CTA, computed tomographic angiography.
Figure 5a. Pseudoaneurysm in a patient with a gunshot wound to zone II of the neck. (a) Axial contrast-enhanced CT image shows focal irregularity of the left vertebral artery and a change in its caliber (arrow). Note the well-defined contour and normal appearance of the right vertebral artery. (b) Selective left vertebral arteriogram shows segmental narrowing of the vessel with a pseudoaneurysm.
Figure 5b. Pseudoaneurysm in a patient with a gunshot wound to zone II of the neck. (a) Axial contrast-enhanced CT image shows focal irregularity of the left vertebral artery and a change in its caliber (arrow). Note the well-defined contour and normal appearance of the right vertebral artery. (b) Selective left vertebral arteriogram shows segmental narrowing of the vessel with a pseudoaneurysm.
**Table 3** Results of Magnetic Resonance Angiography Compared with Arteriography

<table>
<thead>
<tr>
<th></th>
<th>ART Positive</th>
<th>ART Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRA positive</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>MRA negative</td>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>

ART, arteriography; MRA, magnetic resonance angiography.
## Results:

<table>
<thead>
<tr>
<th></th>
<th>CTA</th>
<th>MRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>68%</td>
<td>75%</td>
</tr>
<tr>
<td>Specificity</td>
<td>67%</td>
<td>67%</td>
</tr>
<tr>
<td>PPV</td>
<td>65%</td>
<td>43%</td>
</tr>
<tr>
<td>NPV</td>
<td>70%</td>
<td>89%</td>
</tr>
</tbody>
</table>

### Conclusion:

Arteriography remains the gold standard.
Conclusions

♦ CAI and VAI incidence increasing with improved screening protocols
♦ Morbidity and mortality can be decrease with early diagnosis and treatment
♦ The risk of angiography is less that the risk of an undiagnosed grade I BCVI.
♦ CTA and MRA are insufficient diagnostic modalities and risk increasing morbidity and mortality by delaying diagnosis and treatment
UNIVERSITY OF TEXAS LONGHORNS 2006 BCS NATIONAL CHAMPIONS!
Works Cited

Figure 1b. Right internal carotid arterial occlusion. (a-c) Transverse source images obtained caudad to cephalad at helical CT angiographic examination. In a and b, there is progressive narrowing of the right internal carotid arterial lumen (arrow). In the more cephalic image, c, the artery (arrow) is no longer opacified with contrast material. (d) Sagittal helical CT angiographic image reformatted by means of maximum intensity pixel projection depicts the site of the internal carotid arterial occlusion (arrow).
Figure 2f. Partial occlusion in a patient with a gunshot wound to the left side of the neck (zones II and III). (a) Axial CT image obtained proximal to the bifurcation of the left common carotid artery (arrow) shows obliteration of the perivascular fat planes with displacement and narrowing of the adjacent left jugular vein (arrowhead). (b) Axial CT image obtained just above the bifurcation of the left common carotid artery shows normal calibers of the left internal carotid (IC) and left external carotid (EC) arteries and cephalic extension of the hematoma. (c) Axial CT image obtained cephalad to the IC artery, showing narrowing and posterior irregularity of the left internal carotid artery (arrow), findings consistent with a vascular wall injury. (d-f) Slab maximum intensity projection image (d), surface rendered reformatted angiogram (e), and selective angiogram (f) of the left common carotid artery show the marginal vascular injury and the partial occlusion. In f, the levels of the CT images (a, b, and c) are shown as lines A, B, and C, respectively.
Figure 2e. Partial occlusion in a patient with a gunshot wound to the left side of the neck (zones II and III). (a) Axial CT image obtained proximal to the bifurcation of the left common carotid artery (arrow) shows obliteration of the perivascular fat planes with displacement and narrowing of the adjacent left jugular vein (arrowhead). (b) Axial CT image obtained just above the bifurcation of the left common carotid artery shows normal calibers of the left internal carotid (IC) and left external carotid (EC) arteries and cephalic extension of the hematoma. (c) Axial CT image obtained cephalad to b shows narrowing and posterior irregularity of the left internal carotid artery (arrow), findings consistent with a vascular wall injury. (d-f) Slab maximum intensity projection image (d), surface rendered reformatted angiogram (e), and selective angiogram (f) of the left common carotid artery show the marginal vascular injury and the partial occlusion. In f, the levels of the CT images (a, b, and c) are shown as lines A, B, and C, respectively.
Figure 2d. Partial occlusion in a patient with a gunshot wound to the left side of the neck (zones II and III). (a) Axial CT image obtained proximal to the bifurcation of the left common carotid artery (arrow) shows obliteration of the perivascular fat planes with displacement and narrowing of the adjacent left jugular vein (arrowhead). (b) Axial CT image obtained just above the bifurcation of the left common carotid artery shows normal calibers of the left internal carotid (IC) and left external carotid (EC) arteries and cephalic extension of the hematoma. (c) Axial CT image obtained cephalad to b shows narrowing and posterior irregularity of the left internal carotid artery (arrow), findings consistent with a vascular wall injury. (d-f) Slab maximum intensity projection image (d), surface rendered reformatted angiogram (e), and selective angiogram (f) of the left common carotid artery show the marginal vascular injury and the partial occlusion. In f, the levels of the CT images (a, b, and c) are shown as lines A, B, and C, respectively.
CTA

♦ **Figure 2a.** Left internal carotid arterial occlusion. *(a)* Parasagittal helical CT angiographic image reformatted by means of a volume rendering algorithm. *(b)* Lateral digital subtraction angiogram. The site of the occlusion (arrow in *a* and *b*) is well demonstrated by means of both techniques.
Figure 2c. Partial occlusion in a patient with a gunshot wound to the left side of the neck (zones II and III). (a) Axial CT image obtained proximal to the bifurcation of the left common carotid artery (arrow) shows obliteration of the perivascular fat planes with displacement and narrowing of the adjacent left jugular vein (arrowhead). (b) Axial CT image obtained just above the bifurcation of the left common carotid artery shows normal calibers of the left internal carotid (IC) and left external carotid (EC) arteries and cephalic extension of the hematoma. (c) Axial CT image obtained cephalad to b shows narrowing and posterior irregularity of the left internal carotid artery (arrow), findings consistent with a vascular wall injury. (d-f) Slab maximum intensity projection image (d), surface rendered reformatted angiogram (e), and selective angiogram (f) of the left common carotid artery show the marginal vascular injury and the partial occlusion. In f, the levels of the CT images (a, b, and c) are shown as lines A, B, and C, respectively.
Box 1. Screening criteria to for blunt cerebrovascular injuries

- Cerebrovascular accident or transient ischemic attack
- Neurologic abnormalities unexplained by intracranial injuries or head CT
- Horner's syndrome
- Cervical spine fracture except spinous process fractures
- Basilar skull fracture involving the petrous bone or foramen lacerum
- Massive epistaxis
- Seat belt sign across the neck or chest
- Significant soft tissue injury or large hematoma of the anterior neck
- Injury mechanism compatible with severe hyperextension or flexion and rotation of neck