Carotid Ultrasound Clinical Applications

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Carotid Ultrasound Clinical Applications

- Why do it?
- Highlighting examples/concepts of:
  - Doppler velocities
  - B-mode imaging
  - Duplex and color flow imaging
CEA Specimen: ICA Plaque
Carotid Ultrasound
Clinical Imperatives

• Carotid/Vertebral disease is the most commonly identified stroke mechanism
• Carotid/Vertebral atherosclerosis/stenosis is marker of increased stroke risk
• Established surgical benefit for tight symptomatic carotid stenosis (NASCET) and tight asymptomatic stenosis (ACAS, ACST)
• Efficacy and growth of stenting
Carotid/Vertebral Ultrasound
Clinical Decision-Making

- Carotid ultrasound part of initial vascular evaluation for patients with Stroke or TIA, or at risk for the same.
- Safe, accurate, portable, relatively less expensive, and readily available.
- If CUS negative, usually don’t pursue
- Ideal for serial follow up for progression
Carotid Ultrasound
Common Indications

- Stroke, TIA, Cerebral ischemia
- Bruit evaluation (Sx or Asx)
- Serial follow up of CVD
- Pre-op study, or perioperative in CEA
- Pulsatile neck masses/abnormal structures
- High risk groups to screen for tight stenosis
Carotid/Vertebral Ultrasound
Clinical Questions to Answer

- Is any carotid stenosis present?
- If so, where, what is the distribution, how bad is it, and is it accessible?
- Most Rx decisions still made based on hemodynamic effect (% stenosis)
- Plaque features can influence decision
Vascular Doppler

- Blood cells/components act as moving scatterers (reflectors)
- Imparts frequency shift to scattered Doppler beam (higher or lower)
- Instrument can determine magnitude of Doppler shift in cycles/sec (Hz)
- With AOI can get velocity (cm/s); provides common language across labs/instruments
Doppler Spectral Analysis
FFT Spectral Display
Vascular Doppler
Spectral Analysis Parameters

- Flow direction
- Peak systolic velocity
- End-diastolic velocity
- Spectral pattern (vessel fingerprint)
- Spectral broadening
Doppler Spectral Analysis
Parameters
Hemodynamic Effect of Stenosis
Doppler Velocity Spectral Analysis

Normal ICA Velocity
Doppler Spectral Analysis
Changes with Moderate Stenosis
Doppler Spectral Analysis
Severe Stenosis
Doppler Spectral Analysis
Severe Stenosis/Near Occlusion
Velocity Criteria at WFBMC

- **PRIMARY CRITERIA**
  - Standard angle peak systolic velocity
  - End-diastolic velocity

- **SECONDARY PARAMETERS**
  - Spectral broadening/turbulence, ICA:CCA ratio, resistive pattern in CCA, side differences, extensive plaque on B-mode
## Criteria for Carotid Stenosis

**WFBMC**

<table>
<thead>
<tr>
<th>% Stenosis</th>
<th>PSV</th>
<th>EDV</th>
<th>ICA:CCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 50%</td>
<td>&lt; 140 cm/s</td>
<td>&lt; 40 cm/s</td>
<td>&lt; 2.0</td>
</tr>
<tr>
<td>50-69%</td>
<td>&gt; 140 cm/s</td>
<td>&lt; 100 cm/s</td>
<td>2.0-3.0</td>
</tr>
<tr>
<td>70-99%</td>
<td>&gt; 140 cm/s</td>
<td>&gt; 100 cm/s</td>
<td>&gt;3.0</td>
</tr>
<tr>
<td>Probable Occlusion</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>% Stenosis</td>
<td>Primary Parameters</td>
<td>Secondary Parameters</td>
<td>Parameters</td>
</tr>
<tr>
<td>------------</td>
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<td>------------</td>
</tr>
<tr>
<td>Normal</td>
<td>ICA PSV (cm/s)</td>
<td>Plaque % estimate</td>
<td>ICA/CCA PSV Ratio</td>
</tr>
<tr>
<td>&lt;50</td>
<td>&lt;125</td>
<td>None</td>
<td>&lt;2.0</td>
</tr>
<tr>
<td>50-69</td>
<td>125-230</td>
<td>&gt;50%</td>
<td>2.0-4.0</td>
</tr>
<tr>
<td>70-95</td>
<td>&gt;230</td>
<td>&gt;50%</td>
<td>&gt;4.0</td>
</tr>
<tr>
<td>95-99</td>
<td>High, low, or none seen</td>
<td>Visible</td>
<td>Variable</td>
</tr>
<tr>
<td>Total occlusion</td>
<td>Undetectable</td>
<td>Visible, no lumen</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Grant et al, 2003
Velocity Criteria
ICA:CCA Ratios

- Relationship between velocity at stenotic site and proximal or distal segments
- Higher stenosis, higher ratio
- Remains constant even if bad heart so can’t generate velocity to make stenotic criteria
- ICA:CCA, ICA:Distal ICA validated
- Obtain CCA sample in mid to distal CCA
Indirect Changes
Distal Occlusion
ICA Occlusion
Indirect Changes Proximally
Right ICA String Sign
Right ICA String Sign
ICA String Sign
Distal Turbulence
Effect of Cardiac Disease
Aortic Insufficiency

Right CCA waveform

Left CCA waveform
Contralateral Effects

FR 22Hz 54°
P1
Z 1.1
2D
57%
C 51
P Low
Gen
CF
78%
2825Hz
WF 144Hz
Med

R Prox ICA
PSV -147 cm/s
EDV -47.5 cm/s
RI 0.68

PW
80%
WF 120Hz
SV 5.0mm
M2
4.0MHz
2.1 cm

-120
-80
-40
40
 invoked

6.6 sec
Velocity in Very Proximal CCA
Venous Signal with ICA
Venous Signal with VA
Right ICA Severe Stenosis Case
Resistive Signal in CCA
Right ICA Severe Stenosis
Increased Diastolic Velocity ECA
Right ICA Severe Stenosis
Aliasing with actual systolic velocity >800 cm/s
Right ICA Severe Stenosis
Post-Stenotic Turbulence
Right ICA Severe Stenosis
Decreased Acceleration Slope Distally
Right ICA Severe Stenosis
Reversed OA as Collateral Pathway
Stump Signal

- Right Prox ICA PSV: -33.5 cm/s
- Right Prox ICA EDV: -3.24 cm/s

2D
- HGen
- Gn 66
- C 50
- 3/3/2

Color
- 5.0 MHz
- Gn 57
- 6/6/3
- Fltr Low

PW
- 4.0 MHz
- Gn 26
- 2.4 cm
- Angle 60°
- Fltr 75HZ
- 75 mm/s
ICA Occlusion
Small Caliber Distal ICA
CCA Volume Flow
Distal Occlusion
CCA Volume Flow
Opposite to Occlusion
Carotid B-Mode Imaging
Carotid Protocol & Techniques

Key Elements of Protocol – B-mode

- **B-mode imaging** gives 2-D gray scale image of vessel, wall, plaque, & soft tissue
- **Location, size, course of vessels**
- **Information on plaque features:** location, thickness, surface (smooth, irregular, ulcer), texture (homogeneous/heterogeneous), echodensity, and any movement
Plaque Features:
Smooth and Homogeneous
Irregular Plaque
Calcification/Shadowing
Large hypoechoic ICA plaque

ICA

Residual lumen

CCA

BIF
Plaque Features:
Hypoechoic region/? IPH
Complex Plaque ICA
Thrombosis/Occlusion of ICA
Mobile Thrombus
Longitudinal Pulsation
Mobile Lesion Distal CCA
6 months before stroke
Mobile Lesion Distal CCA
Transverse View
CCA Dissection
Distal CCA Dissection
ICA Dissection
Caution Side Wall Plaque
Transverse Truth
Prior CEA Suture Line
Typical Take-off of Superior Thyroidal
Low Take-Off of Superior Thyroidal Artery
Distal Take-off of Superior Thyroidal
Distal CCA Cut-off from Prior CEA
Abrupt CCA Cut-off From Prior CEA
Dacron Patch Graft ICA Post-CEA
Dacron Patch Graft Post-CEA
Proximal, Transverse, with Plaque
Internal Jugular Spontaneous Echo Contrast
Internal Jugular Thrombosis
Color Flow Imaging CCA
Color Flow Imaging

- Quick ID presence/direction of flow
- Road map for spectral Doppler
- More accurate angle of insonation
- Improved data on surface features
- ID of hypoechoic plaque (color void)
- ID string sign/near occlusions
- Speed up examination
Color Changes
Direction of Flow Relative to Transducer
ICA Loop
Color Flow Tight Stenosis
Color Flow Imaging
Color void of hypoechoic plaque - transverse
Boundary Layer Separation
Stent: Proximal End
Stent: Color Flow
Stent Stenosis
Post-Stenotic Turbulence

LT CCA

FR 22Hz 60°
P1 Z 1.4
2D 50%
C 50
P Low
Gen CF
78%
2625Hz
WF 144Hz
Med

R Dist CCA
PSV 299 cm/s
EDV 70.7 cm/s
RI 0.76

PW 84%
WF 200Hz
SV 4.0mm
M2
4.0MHz
2.4cm

6.6sec
Color Blooimg
Large ICA Plaque
Color Blooming Beyond True Lumen
Color Blooming Power Doppler
Normal Appearing Thyroid - Right
Thyroid – Increased Vascularity, Small Cyst
Multiple Small Thyroid Cysts
Cerebrovascular Anatomy

- Posterior communicating artery
- Basilar artery
- Vertebral artery
- Internal carotid artery
- External carotid artery
- Middle cerebral artery
- Anterior cerebral artery
- Ophthalmic artery
- Innominate artery
Color Flow Vertebral Origin
Duplex Interosseous Vertebral
Vertebral/Subclavian Steal

WFBH CARO
L12-3
21Hz
4cm

2D
HGen
Gn 78
C 50
3/3/2

REVERSED

PW
4.0 MHz
Gn 46
3.0 cm
Angle 60°
Fltr 75HZ
75 mm/s

Right
Vertebral A PSV -54.9 cm/s
Vertebral A EDV -6.30 cm/s
Put It All Together
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