Instructor's Digital Curriculum Resource-

For Techniques in Noninvasive Vascular Diagnosis-4th edition.

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Instructor's Digital Curriculum Resource-

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Alternatively, the movies (provided) can be re-inserted into PowerPoint

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Chapter 2.
Carotid Color Duplex Imaging

Techniques In Noninvasive Vascular Diagnosis – 4th edition

Definitions for this chapter

- MI- myocardial infarction- heart attack
- DM- diabetes mellitus
- Hypertension- high blood pressure
- PAD- peripheral arterial disease
- ICA- internal carotid artery
- ECA- external carotid artery (outside the skull)

Definitions for this chapter

- ICA Bulb- dilation of the CCA at the bifurcation, also, the proximal ICA segment.
- Plaque- atherosclerotic disease within the wall of the artery
- Morphology- shape and appearance
- Spectra (spectral) – pertains to the Doppler waveform display.

Definitions for this chapter

- Spectral broadening- a filling-in of the spectral display waveform
- Spectral envelope – the clear region within the waveform underneath systole
- Lumen, residual lumen – the inside dimension of the artery.
- Infarct
  - tissue death caused by a local lack of oxygen

Definitions for this chapter

- Collateral vessel, collateral flow-
  - a vessel that carries flow, or more flow, to compensate for an obstruction in the primary source vessel.
- Contralateral- opposite side
- Ipsilateral – same side
- Anomalous (anomalies)- deviation from what is normal

Cerebrovascular Symptoms

- Cerebrovascular accident– CVA- stroke
  - permanent or semi-permanent impairment
- Transient Ischemic Attack- TIA
  - symptoms resolve within 24 hrs.
- Death is a possible outcome

Common Hemispheric Symptoms:

- Speech difficulty- usually left hemisphere
  - Aphasia
    - inability to speak or express oneself
  - Dysphasia
    - Impairment of speech, failure to arrange words correctly.
  - Dysarthria
    - imperfect articulation, due to disturbances in muscle control

Common Hemispheric Symptoms:

- Lateralized paresthesia:
  - numbness and tingling of extremities
- Hemiparesis:
  - weakness on one side of body, face, arm, leg.
- Hemiplegia:
  - total paralysis of one half of body, face, arm, leg.
- Visual disturbances- ipsilateral
  - transient monocular blindness
  - amaurosis fugax

Amaurosis Fugax

Ipsilateral symptom

"shade being drawn over one eye field of view"

Common Hemispheric Symptoms:

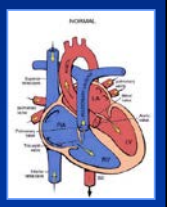
- Generalized weakness-motor dysfunction
- Ataxia- gross incoordination of muscle movement, clumsiness of limb
- Sudden confusion, trouble speaking or understanding speech.
- Sudden severe headache with no known cause.
- Death

Vertebral-basilar Symptoms

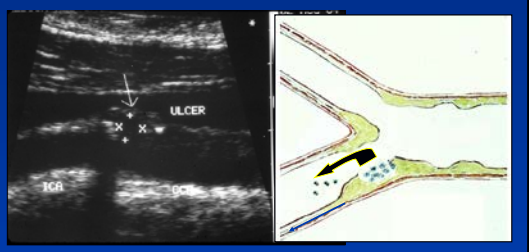
- Drop attacks
- Syncope
- Vertigo
- Dizziness
- Diplopia (double vision)
- Blackouts
- Memory loss

CVA Causes

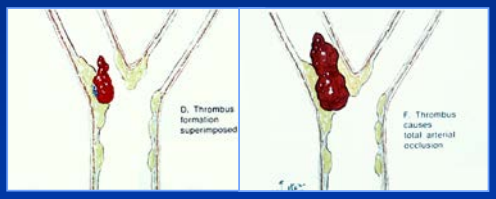
- Cardiac origin
  - emboli
  - cessation of perfusion
- Carotid origin
  - thrombosis- occlusion
  - Athero. stenosis decreasing perfusion
  - emboli to brain



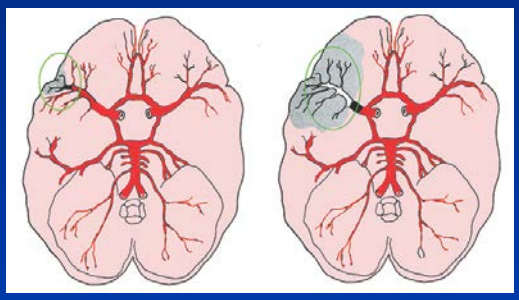
Ulceration- "The Room of Doom" source of emboli



Carotid Etiology- Thrombosis



Small emboli-small infarct Large emboli-large infarct



CVA Causes

- Cerebral Aneurysm Rupture
  - Intracranial hemorrhage- subarachnoid hemorrhage (SAH) from ruptured aneurysm
  - Approximately 15% of strokes are hemorrhagic
  - Vasospasm –a spasm of the intracranial arteries following SAH

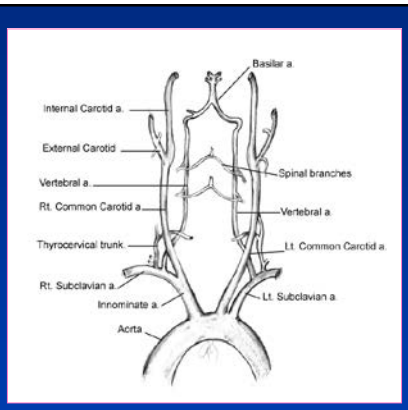
Berry aneurysm

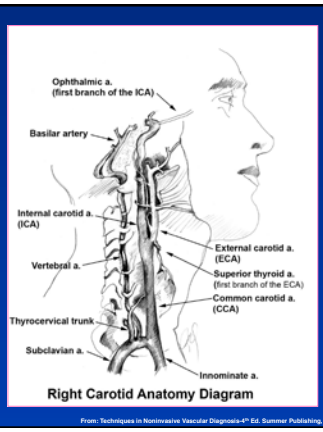
CVA Causes

- Miscellaneous
  - Vasospasm due to sickle cell anemia
  - Congenital cerebral arterial-venous malformation

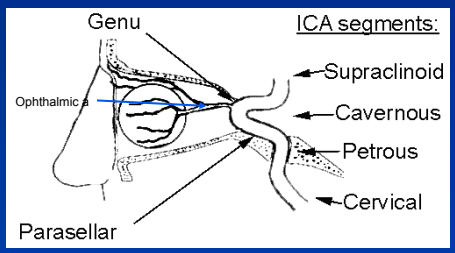
Cerebrovascular Disease Risk Factors

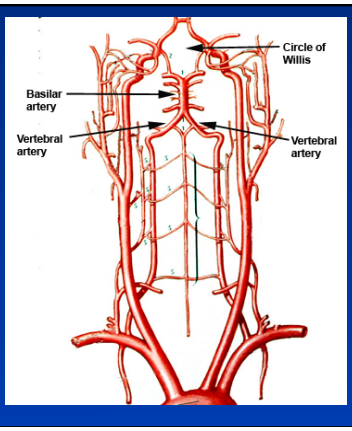
- Family history of PAD, Heart Disease
- Smoking
- Old Age
- Diabetes mellitus
- Hypertension
- High cholesterol



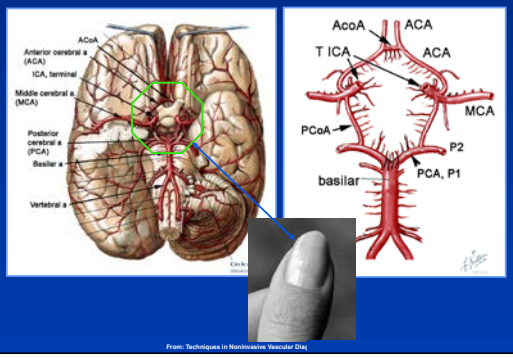


ICA "Siphon"





Circle of Willis



Circle of Willis Anomalies

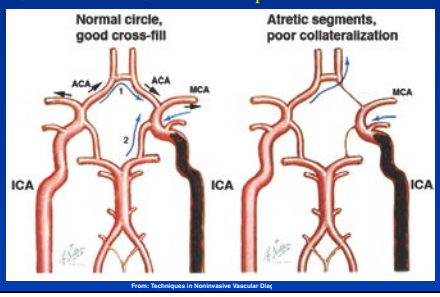
- Only 50% of population have an intact and functioning circle (estimated).
- Only 25 % have the classic configuration.

Incomplete circles

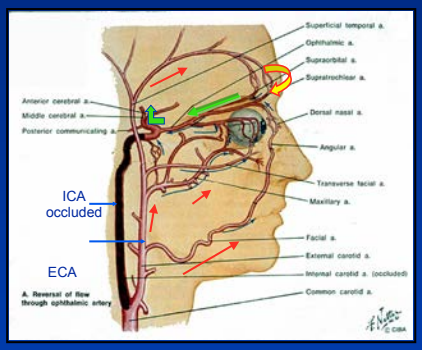
Incomplete circle in patients with ICA occlusion

Normal circle, good cross-filling to MCA

Atretic segments, poor collateralization



ECA collateral pathways



Protocol

- Patient history
- Transverse imaging
- Longitudinal imaging
- Color Doppler
- Spectral Doppler
- "mapping" of any areas of flow disturbance

Pertinent Patient History

- Describe neurologic symptoms
- Myocardial infarct?
- Hypertension (HT) ?
- Diabetes (DM) ?
- Smoking? (record # packs per day/ years)
- Vascular or cardiac operations?

Bad scan positions

Scan Positions –Required Elements

- Must be able to achieve a posterior-lateral position for ICA evaluation
- Must have forearm and hand supported by pillow or bed.
- Must be able to hold a small sample volume in a small (1mm) residual lumen without “drifting” for several cardiac cycles.

Bad Scans

Not bad, but not as good as below

Very Good

Good Attempt at Posterio-lateral Scan

Good Scan Position for Right Neck

Left Neck, Good Scan Positions.

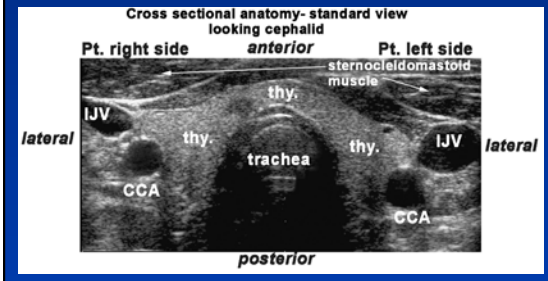
Hand and arm must be stable, you must be able to scan from Posteriolateral plane.

Transverse Imaging

- Use anterior, posterior and lateral approaches.
- Usually, best approach for ICA is posterior-lateral. diameter measurement of stenosis
- ICA -ECA identification /differentiation
- Common imaging error among beginners is using anterior-lateral approach for ICA

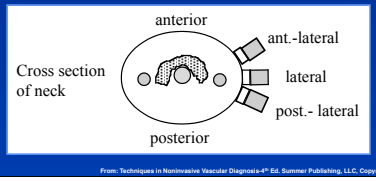
Cross-Sectional Anatomy

standard view, looking cephalad



Transverse Imaging: Use various transducer positions

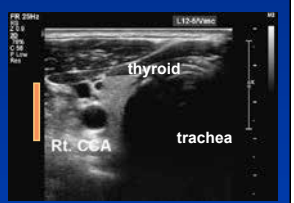
Anterior-lateral Lateral Posterior-lateral



Anatomy rules

Transverse Scan Right Neck

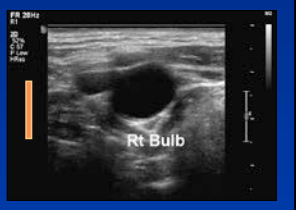
- Orientation: thyroid should be to the right of the Rt. CCA



Orange bar = posterior direction

Transverse Bulb

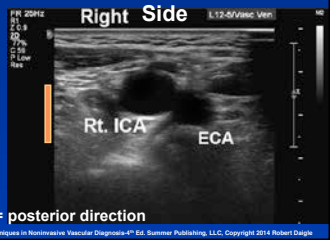
- Move transducer to lateral position



Orange bar = posterior direction

Transverse: bulb-bifurcation

- ICA will be on the left side of the screen, (opposite the thyroid)
- Swing transducer posterolateral

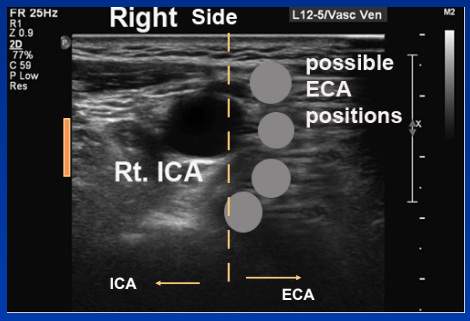


Orange bar = posterior direction

ICA - ECA

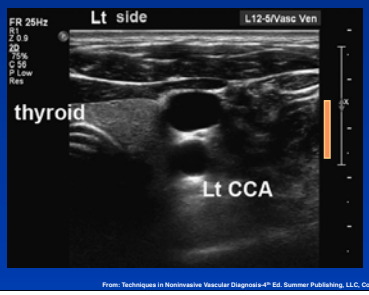
- The ICA lies posterior in the neck in 95% of patients
- If you know where "posterior" is in the field of view, you can identify the ICA

Possible ECA positions



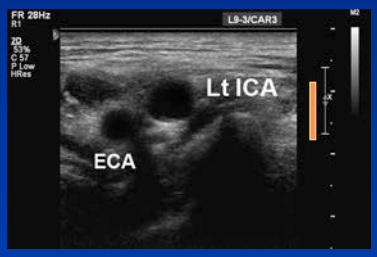
Transverse Anatomy Left Side

- Orientation: thyroid should be to the left of the Lt. CCA



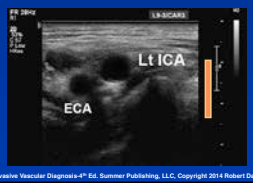
Transverse: bulb-bifurcation

- ICA will be on the right side of the screen, (opposite the thyroid)



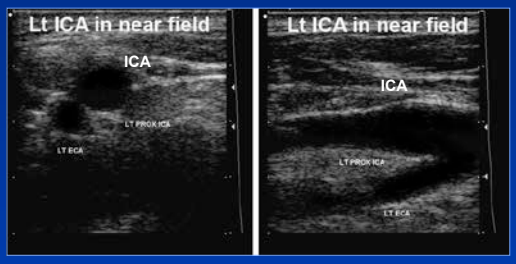
Next step in anatomy ID

- Use the transverse location to predict ICA location in longitudinal plane
- If the ECA is in "far field", it will be in the far field on longitudinal image (assuming same scan plane, lateral or posterior lateral)



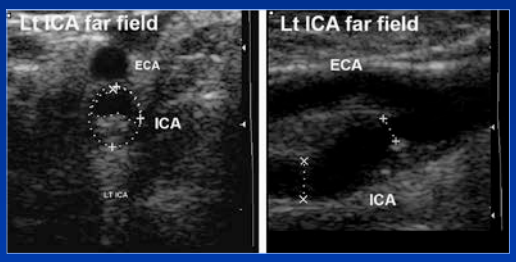
Patient #007

ICA in near field in transverse, also in near field in sagittal



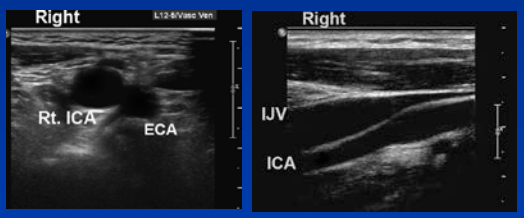
Patient #008

ICA in far field in transverse, also in far field in sagittal



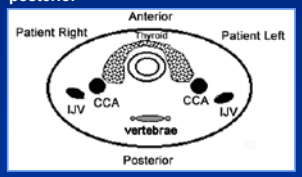
Patient #009

ICA & ECA lie at approx. same depth in transverse, so in sagittal each vessel will appear at same depth, you'll see one or the other.



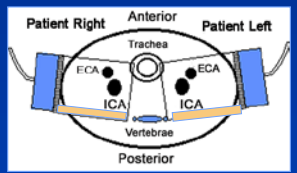
Why the far field is not "posterior"

Cross- sectional anatomy

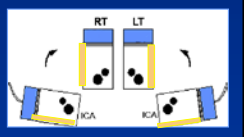


Transducer scan positions

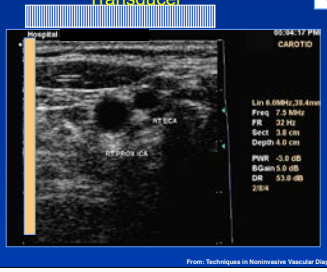
= posterior

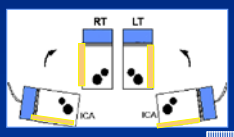


Patient right side



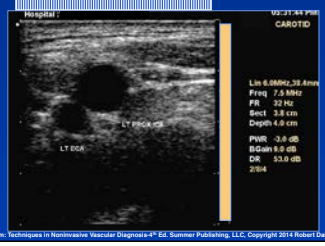
Transducer





Patient left side

Transducer



Transducer Orientation

- Most transducers have a notch, indentation or ridge to help with orientation
- In transverse right, the notch should be down, towards the bed.
- In transverse left, the notch should be upwards, towards the ceiling.
- Beware, some transducers have a notch on both ends!

ICA - ECA differentiation

(most common error)

- Anatomy
  - posterior position of ICA
  - branches of ECA
  - ICA size: not reliable when diseased
- Doppler waveforms & sounds
  - ICA = low resistance
  - ECA = high resistance

Longitudinal Image

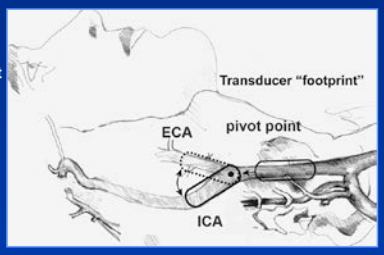
- Anatomy
- Plaque characterization
- Doppler

Longitudinal:
ECA best imaged from anterolateral, ICA best imaged from posterolateral

From the distal CCA, pivot the transducer towards the chin to view the ECA, and towards the bed for the ICA.

When in PowerPoint Show. click on link below for video demo on youtube.

http://youtu.be/8dlERm5O2QY

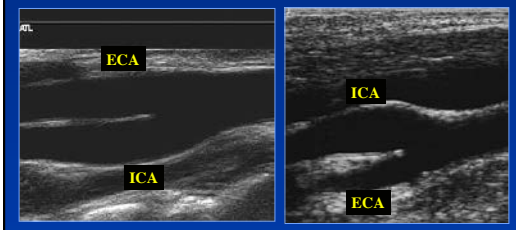


Far-field in field of view in a typical carotid exam is NOT anatomically "posterior" (unless the transducer is positioned over the trachea!)

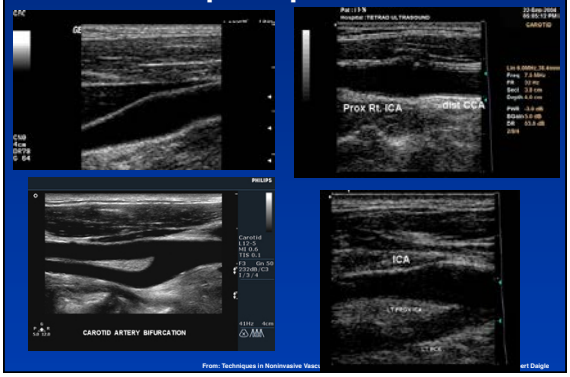
ICA lies posterior in the neck 95%

This is not posterior!

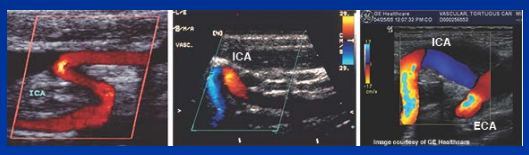
ICA may lie deep or superficial to the ECA



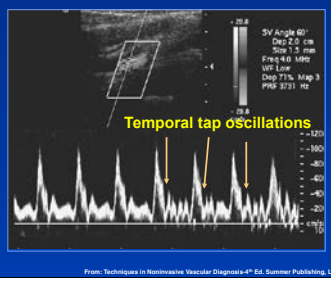
Bulb shape of proximal ICA



Tortuous vessels are a challenge!



ECA Temporal Tap can be a useful tool in identifying the ECA, but it is often unreliable. Oscillations can and do occur in the ICA as well.
Understanding the anatomical position of the ECA-ICA is the best method.



Plaque Morphology

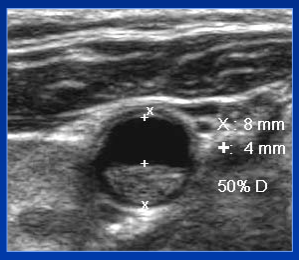
Plaque Morphology

Measuring Plaque

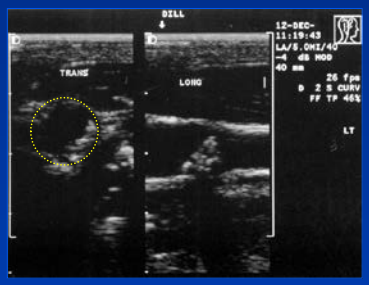
Diameter measurements of plaque are sometimes used to estimate % stenosis

% D stenosis =

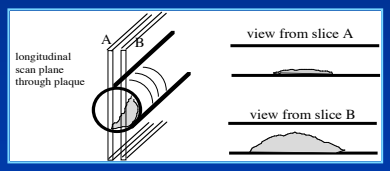
$$\frac{TL - RL}{TL} \times 100\%$$



This minor plaque can be made to appear more or less stenotic in longitudinal view



- Longitudinal estimation of stenosis from B-mode image is often unreliable, use transverse image.



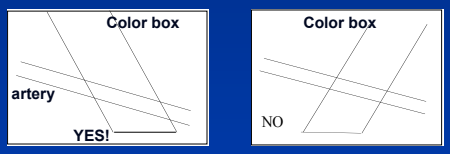
Longitudinal view, in some circumstances, can exaggerate amount of plaque.

If the movie does not play, Click on Link (in Powerpoint Show)
To play Youtube video

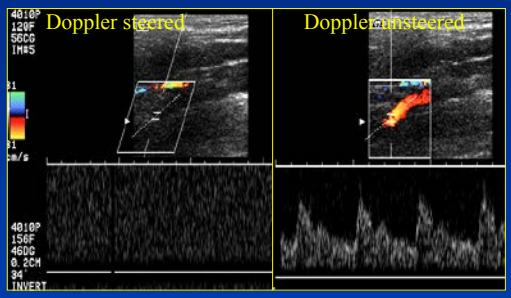
http://youtu.be/TQ9NnN3mMk4

Movie=-Transverse plaque-longplaq.sm.wmv

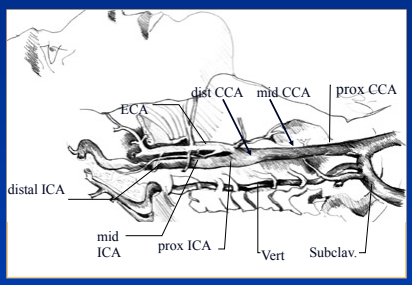
Color Doppler beam steering is often altered in a carotid exam. You must optimize color settings.



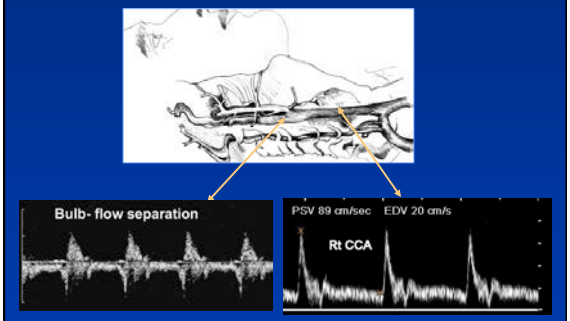
Depth penetration may be improved by not steering the Doppler



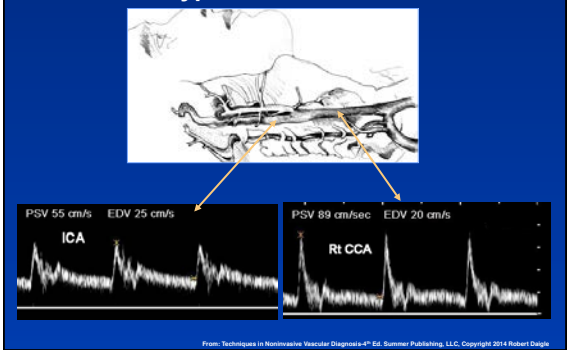
Doppler Sample Locations



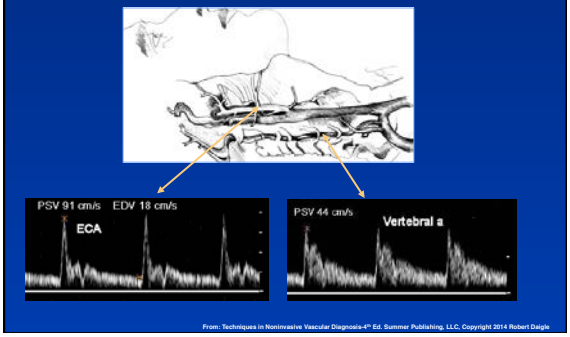
Typical Waveforms



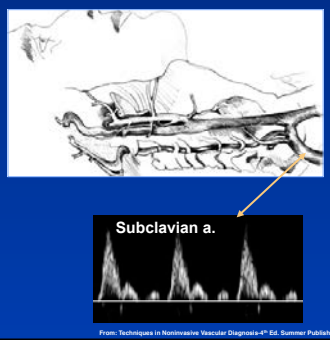
Typical Waveforms



Typical Waveforms



Typical Waveforms



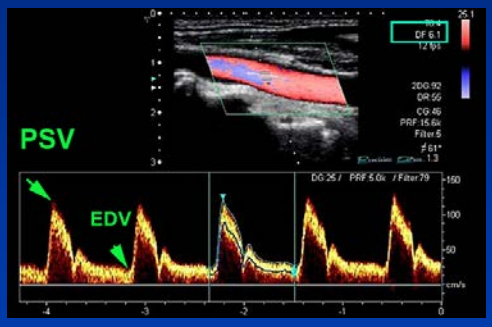
Doppler Measurements

- CCA- peak systolic velocity (PSV) and end-diastolic velocity (EDV)
  - Proximal, mid, distal or at stenosis
- ICA- PSV & EDV
  - At maximum stenosis, if present
  - Proximal. mid, distal
- ECA- PSV only
  - Proximal or at stenosis

Doppler Measurements

- Vertebral- PSV, (EDV optional)
  - Mid vertebral
- Subclavian- PSV only

PSV, EDV

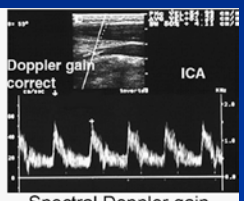


Optimize Spectral Doppler

- Doppler should be steered in the appropriate direction, left, right, or center
- Sample volume size is 1-3 mm, use a large SV in stenosis.
- Adjust spectral scale (PRF) so that waveforms are 1/2 -2/3 of scale
- Angle correction cursor carefully aligned to axis of flow (or vessel wall)

Optimize Doppler Gain

Spectral Doppler gain is too high, spectral broadening could mimic turbulence flow.



Spectral Doppler gain is adjusted correctly.

General Considerations

- Significant velocity acceleration occurs at stenosis of 50% diameter or greater
- Velocities do not appreciably increase over stenosis less than 50% D (30% by NASCET measurement)

General Considerations (2)

- Most stenoses of > 50% cause significant post-stenotic turbulence
- A focal velocity acceleration over the plaque, followed by turbulence is an essential finding for a 50-60% or greater stenosis

Criteria: Objective Parameters

- Stenosis diameter measurement (optional)
- Peak systolic velocity at max stenosis (PSV).
- Peak end-diastolic velocity at max stenosis (EDV).
- ICA/CCA ratio (PSV at point of max stenosis ÷ PSV from a disease-free segment (mid) of CCA)
- Absence of flow (occlusion)

Fundamental Concept

- Carotid criteria is meaningless unless there is:
  - Focal velocity acceleration
  - Plaque
  - Post stenotic turbulence
- Criteria is for "grading" stenosis, NOT for determining normalcy.

Criteria Generalizations

- Know your Carotid Criteria.
  - 50 -69% diameter stenosis
    - Visualization of plaque
    - Focal velocity acceleration
    - Post stenotic turbulence
    - PSV at max sten > 140 cm/s
    - EDV less than 100 cm/sec

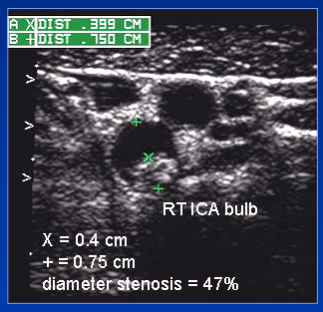
Criteria Generalizations

- 70-95% diameter stenosis
  - Visualization of plaque
  - Focal velocity acceleration
  - Post stenotic turbulence
  - EDV greater than 100 cm/sec
  - ICA/CCA ratio > 4.0

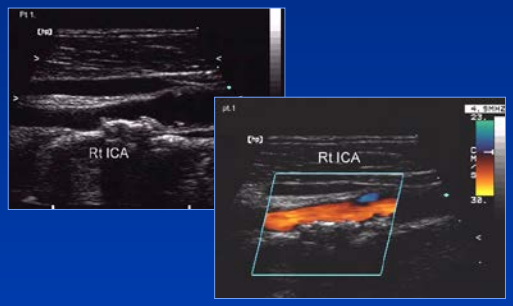
"Mapping" a Stenosis.

- Visualize plaque
- Work the Doppler sample volume through the stenotic region (think 3 dimensions!)
- Record and measure highest velocity (take 2 or 3 samples)
- Sample and record distal to stenosis to detect turbulence (if any).

Patient #1: < 50% ICA stenosis

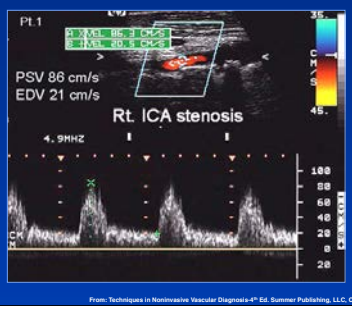


Patient #1: < 50% ICA stenosis

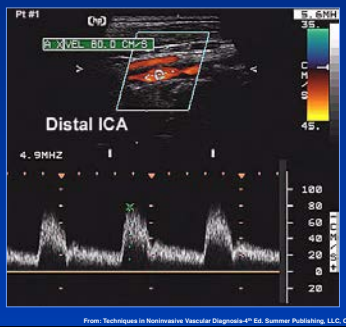


Patient #1: < 50% ICA stenosis

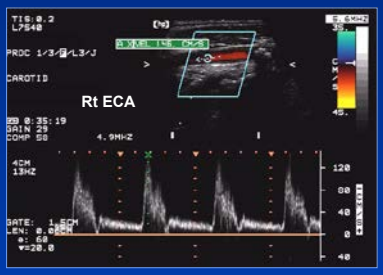
Patient #1: < 50% ICA stenosis- no velocity increase over stenosis



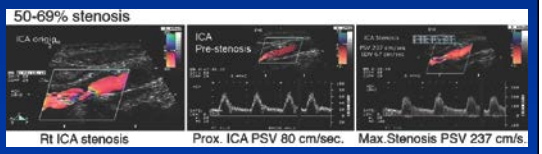
Patient #1: < 50% ICA stenosis



Patient #1, ECA



50-69% ICA stenosis



Video demo.
50-69% ICA stenosis

Also
Proximal Rt. Vertebral stenosis

50-69% ICA Stenosis

If the movie does not play, Click on Link (in Powerpoint Show) To play Youtube video

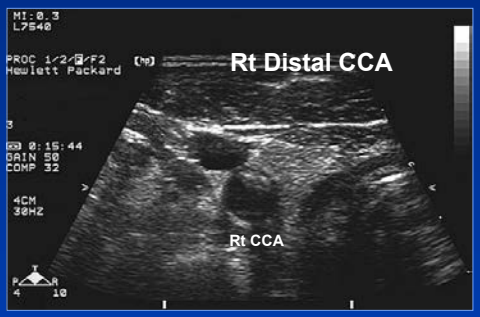
http://youtu.be/khlJ6Kfg38I

Movie, Pt. Dre-50-69%-LAN-dubbed

Demonstration of a 70-95% ICA stenosis- patient "3"

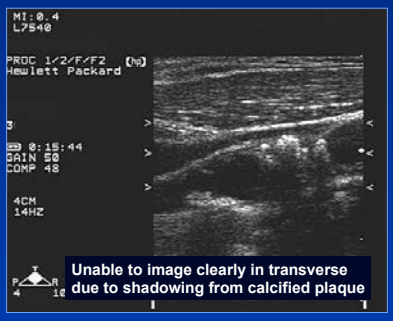
Patient #3

70-95% Stenosis



Patient #3

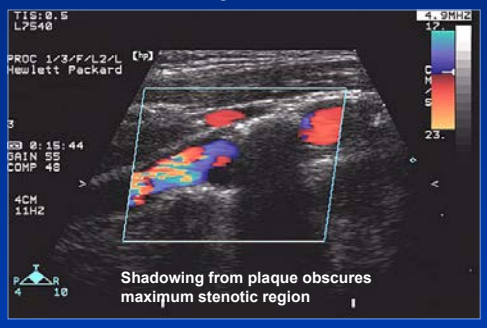
Rt. Bulb and ICA



Unable to image clearly in transverse due to shadowing from calcified plaque

Patient #3

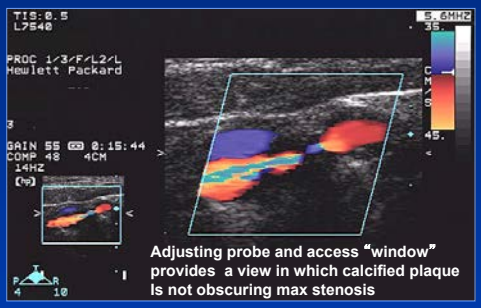
Rt. ICA



Shadowing from plaque obscures maximum stenotic region

Patient #3

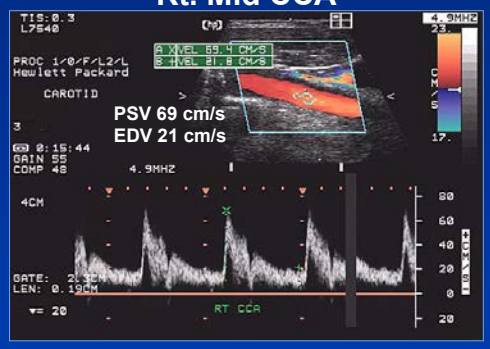
Rt. ICA



Adjusting probe and access "window" provides a view in which calcified plaque Is not obscuring max stenosis

Patient #3

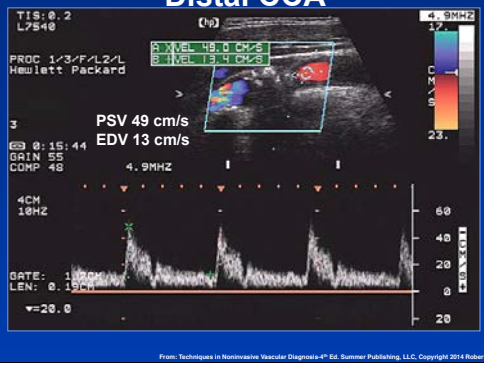
Rt. Mid CCA



PSV 69 cm/s
EDV 21 cm/s

Patient #3

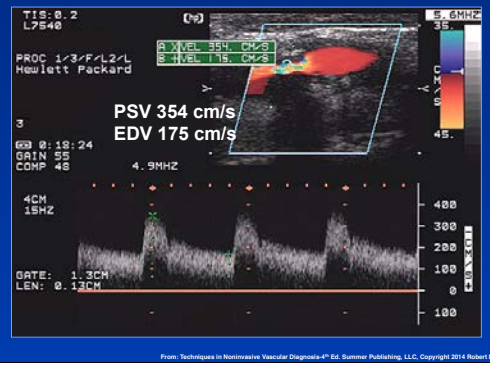
Distal CCA



PSV 49 cm/s
EDV 13 cm/s

Patient #3

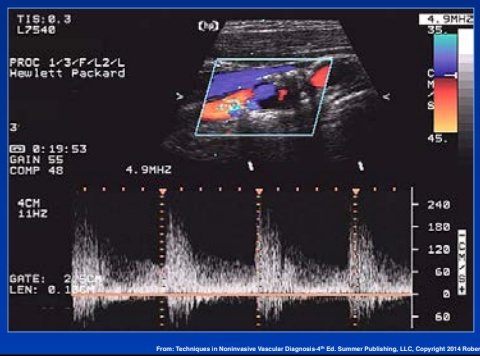
Maximum Stenosis



PSV 354 cm/s
EDV 175 cm/s

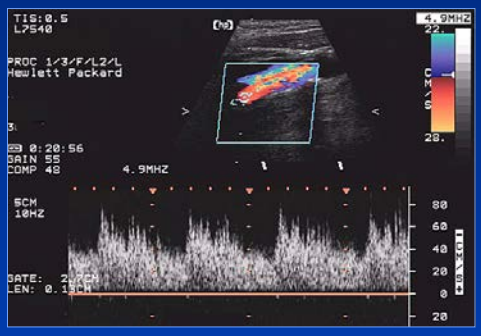
Patient #3

Post-stenotic Turbulence



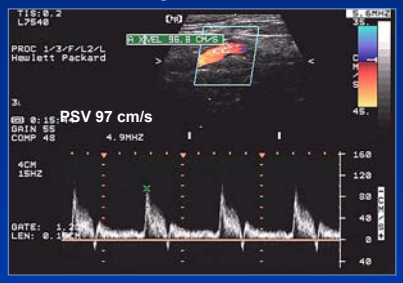
Patient #3

Distal Rt. ICA



Patient #3

Rt. ECA



Proximal CCA and Vertebral arteries were also evaluated but are not presented in this series.

Patient 3, Comments

- Unable to estimate diameter reduction from image due to calcified plaque.
- Velocity decreases just before stenosis, then accelerates.
- ICA/CCA ratio = 5.1
- PSV 354 cm/s EDV = 175 cm/s
- Severe post-stenotic turbulence which persists in the distal ICA
- > 70% stenosis by NASCET method
- > 80% stenosis by traditional criteria

Video demo of 70-95% stenosis

If the movie does not play, Click on Link (in Powerpoint Show) To play Youtube video

http://youtu.be/pwfmQ2E4Udl

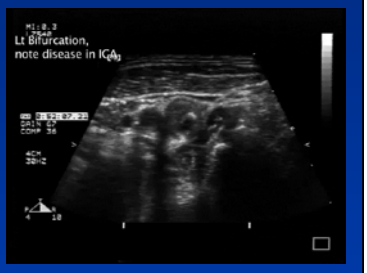
70-95% stenosis, same patient #3

Movie JCob-80% dubbed-for web

Video demonstration of a >90% stenosis

- Note low, high resistance flow just before ICA stenosis.
- Note low velocity and abnormal waveforms in distal ICA
- Note the difficulty in obtaining a good Doppler sample at max stenosis

>90% Stenosis



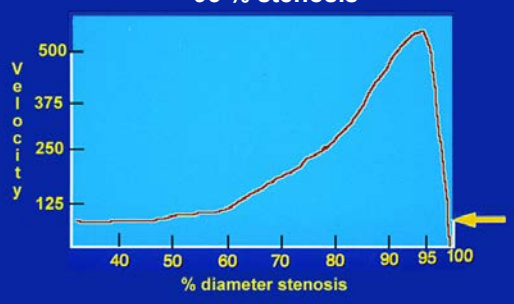
If the movie does not play, Click on Link (in Powerpoint Show) To play Youtube video

http://youtu.be/NMiyY6TW1Qc

Cdrei-ICA-90-dubbed.sm.wmv

> 95% stenosis and "trickle" flow.

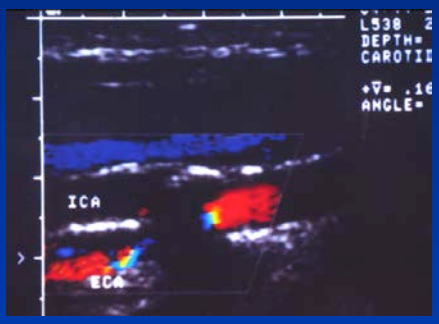
> 95 % stenosis



Velocity within a stenosis increases until a certain degree of narrowing. At stenoses of >95% D, velocity decreases.

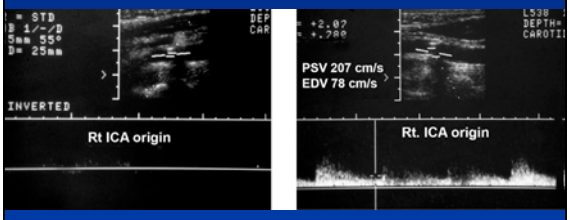
Patient #7

Pt. # 7: >95% stenosis



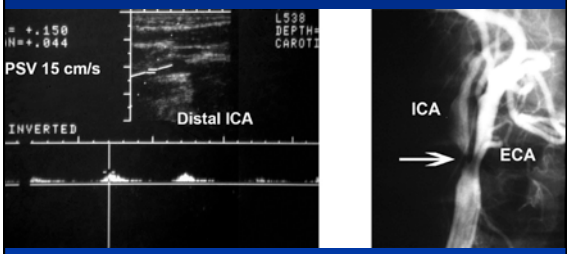
Patient #7

Initially, no flow detected. Calcium??



Doppler beam redirected under plaque to achieve a weak signal

Patient #7

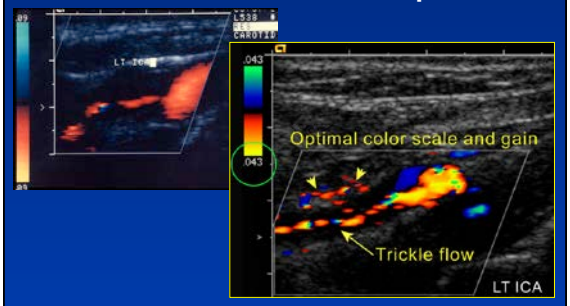


Pt #7, Comments

- Very difficult to obtain a Doppler sample at max stenosis
- PSV 207 cm/s and EDV of 78 would indicate a less than 70 % (Nascet)
- However, low flow and velocity distal to stenosis suggests a much tighter stenosis.
- Angiography confirmed a > 95% stenosis

Residual lumen can become so small than velocity becomes very slow, i.e., Trickle flow

Trickle flow in a nearly occluded ICA- 2 examples

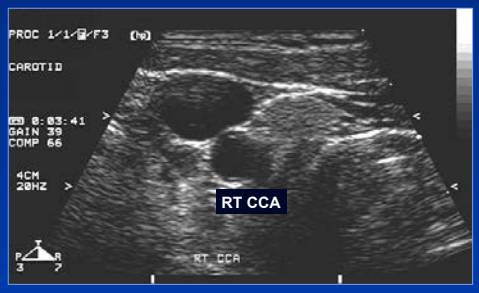


Low Color PRF scale are used, otherwise flow was not seen.

Total ICA Occlusion

Patient #4

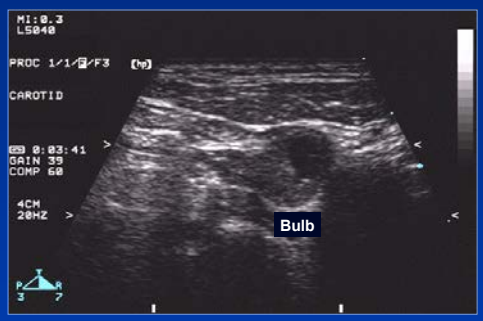
Rt. CCA Transverse



Occluded ICA

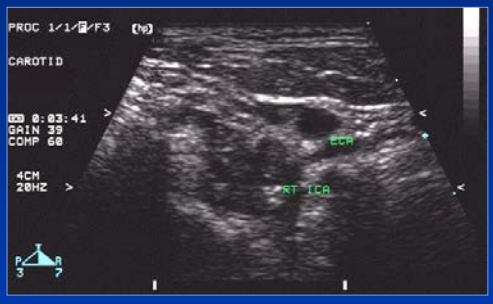
Patient #4

Rt Bifurcation



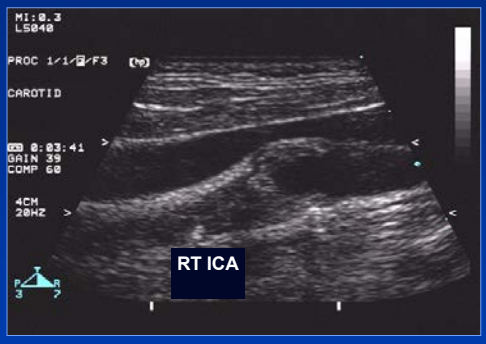
Patient #4

Rt Bifurcation



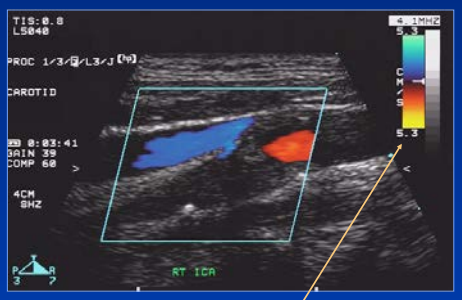
Patient #4

Rt ICA – Long.



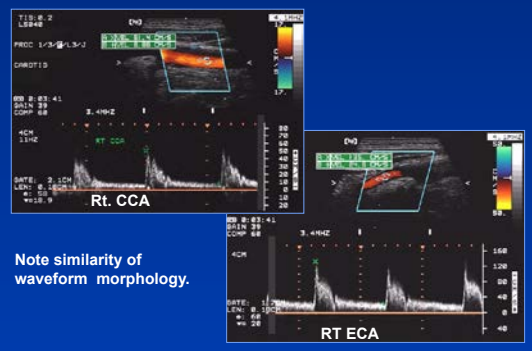
Patient #4

Rt ICA



Note low color scale used to detect possible "trickle" flow.

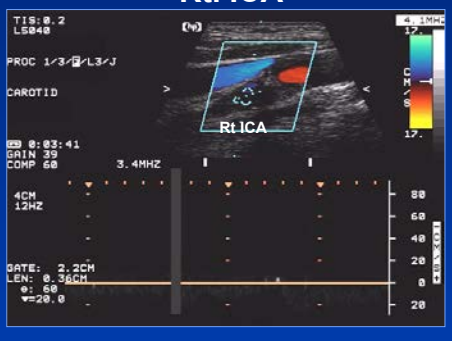
Patient #4



Note similarity of waveform morphology.

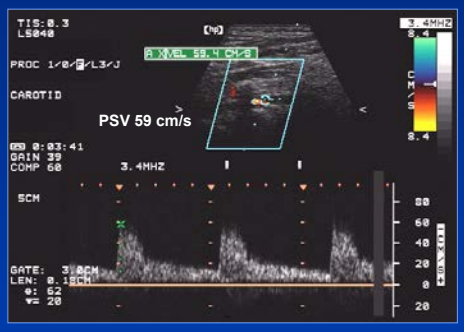
Patient #4

Rt. ICA



Patient #4

Rt Vertebral

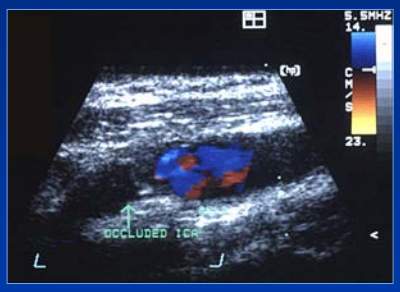


Patient 4, Comments

- Occluded Rt. ICA
- Waveform patterns in CCA and ECA are similar because they are now essentially one vessel.
- ICA sampled in numerous locations, wide sample volume used
- Various color scales used, it's important to use a low scale when looking for possible trickle flow.

Patient #6

Occlusion: Potential Pitfall



Occluded vessel: ICA or ECA??

Patient #6

RT CCA

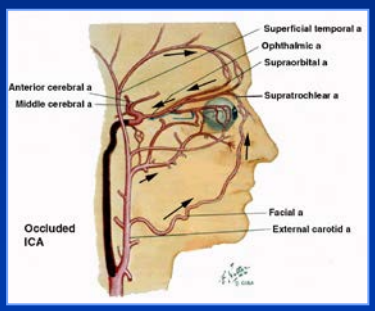
CCA with low resistance flow pattern.

Patient #6

ECA or ICA??

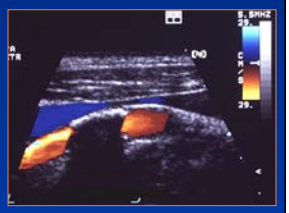
ECA has become "internalized", i.e., it's functioning as a collateral pathway and has low resistance flow.

Potential Collateral Pathways with ICA Occlusion



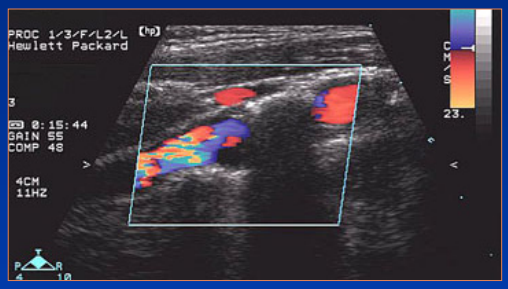
How to deal with calcified plaque.

Far-field wall, no problem!

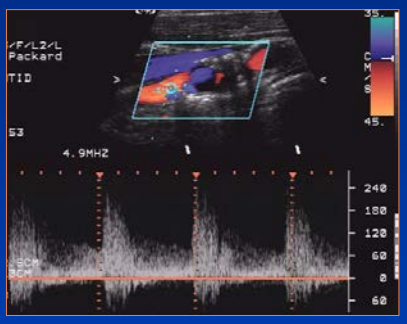


Near-field wall, potential problem, Look for post-stenotic turbulence.

Max Stenosis Under Calcium



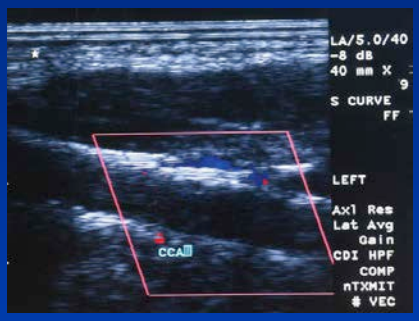
Post-stenotic turbulence means >50% stenosis, but it may be more severe.



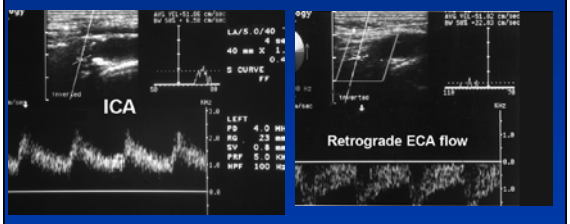
Uncommon Pathologies

- Occluded CCA
- Fibromuscular dysplasia
- Carotid dissection
- Proximal occlusive disease

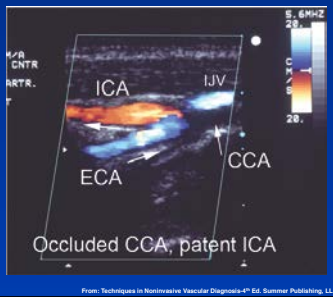
CCA Occlusion



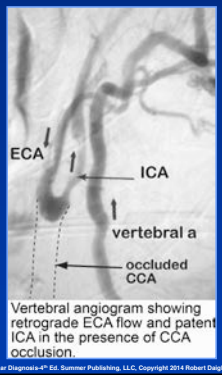
CCA Occlusion



Retrograde flow in ECA supplying ICA; the opposite can also occur

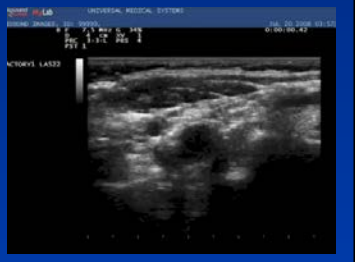


CCA Occlusion with Patent ICA



Vertebral angiogram showing retrograde ECA flow and patent ICA in the presence of CCA occlusion.

Demo of a Tortuous ICA



If the movie does not play, Click on Link (in Powerpoint Show)
To play Youtube video

http://youtu.be/oh-yns09Lzo

Fibromuscular Dysplasia

- A non-atherosclerotic, non-inflammatory arterial disease of unknown causes
- Fibrous thickening of the intima, media, or adventitia

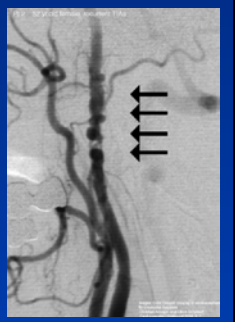
ICA angiogram of FMD

Fibromuscular Dysplasia (FMD)

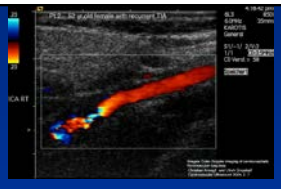
- predominance in women (90%)
- associated with hypertension
- proximal and distal ICA spared
- usually bilateral
- known to occur in renal arteries

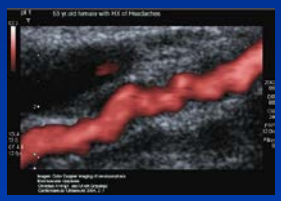
FMD

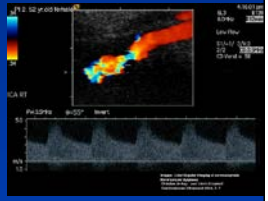
- 77% present with cervical bruit
- Angio = "string of pearls"
- Color Duplex- distal ICA turbulence w/wo increase velocity



FMD

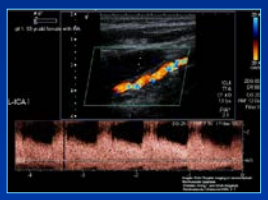






FMD Scan Protocol

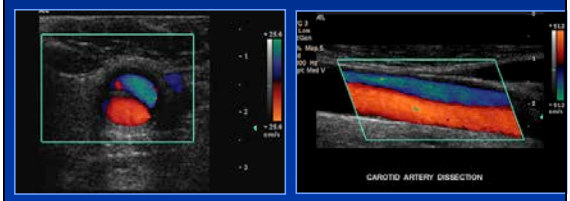
Scan ICA "way distal" on middle-aged females, especially with bruits and if no athero disease in bulb



Carotid Dissection proximal

- common carotid artery
- progression of aortic dissection
- false lumen
- asymptomatic (usually)
- ICA extension, uncommon

CCA Dissection



Courtesy of Philips Ultrasound

Carotid Dissection distal

- mid to distal ICA
- no false lumen
- subintimal hematoma
- flow restrictive
- symptomatic

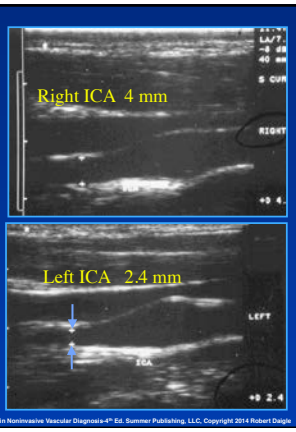
Distal Dissection Symptoms

- Hemispheric ischemia and stroke
- Headache
- Ipsilateral neck pain

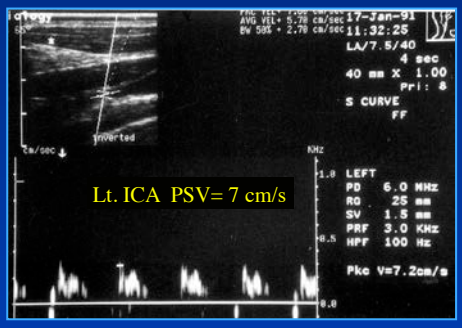
Carotid Dissection Etiology

- Congenital defects in media
- Fibromuscular dysplasia
- Trauma
- Forced neck extension
- Idiopathic

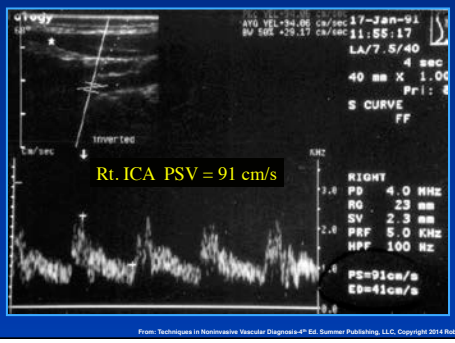
Patient K.S.
43 year old female
Acute onset speech difficulty
No MI, CVA, HT, Smoking



K.S. Lt ICA



K.S. Rt. ICA



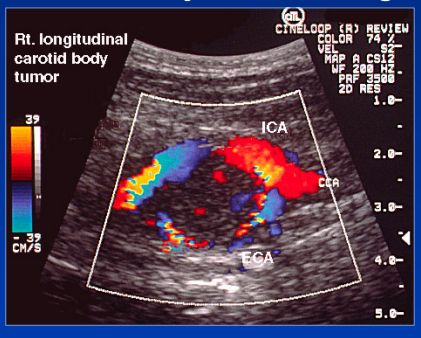
Lt Angio, Jan 17

Lt. Angio, April 3

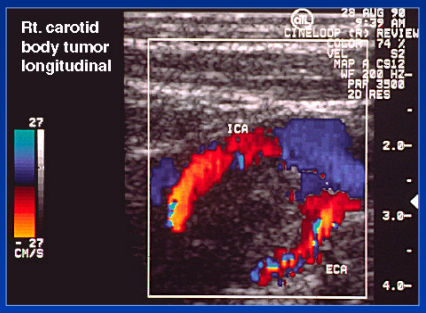
Carotid Body Tumor

- aka, chemodactoma
- Highly vascular
- Usually benign
- Lies in the "crotch" of the carotid bifurcation

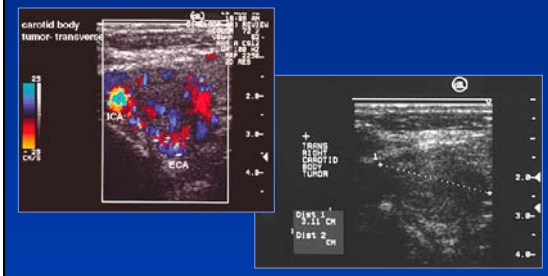
Carotid Body Tumor – Long.



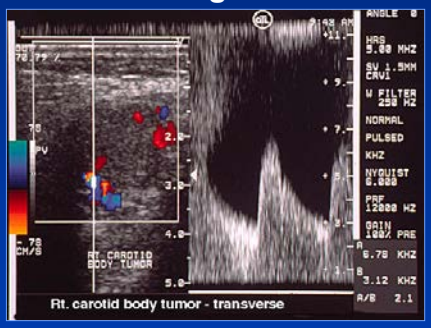
Carotid Body Tumor – Long.



Carotid Body Tumor- Transverse



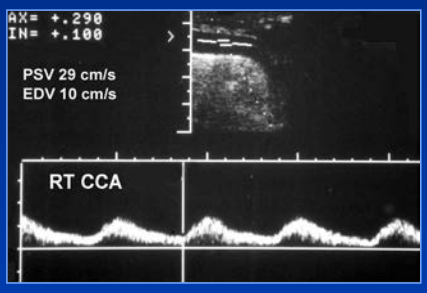
CBT- High Flow



Proximal Cerebrovascular Disease

- A "rounding" of the CCA waveform with loss of amplitude and delayed rise time (tardus parvus) suggests proximal stenosis or occlusion.
- On right side, evaluate the innominate artery.

CCA Waveform: Patient with Innominate Artery Stenosis



Carotid Stents

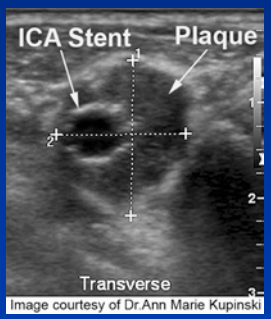
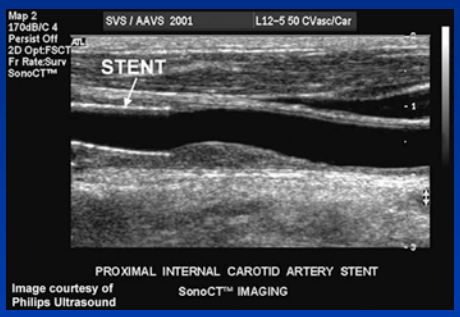
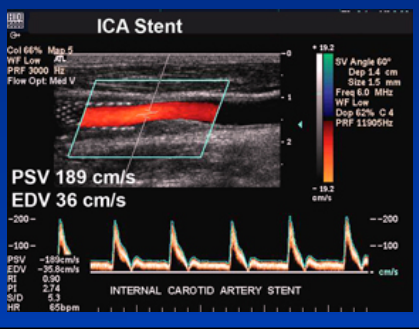


Image courtesy of Dr.Ann Marie Kupinski

Carotid Stents

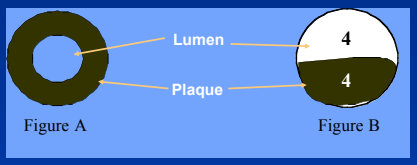


Carotid Stent



Stent Restenosis Criteria is in Chapter 3

Addendum
Area versus Diameter



In "A", Circumferential plaque, 75% Area = 50% Diameter reduction

In "B", 50% area reduction is also a 50% Diameter reduction