Carotid Duplex Ultrasonography: B Mode and Spectral Dopper

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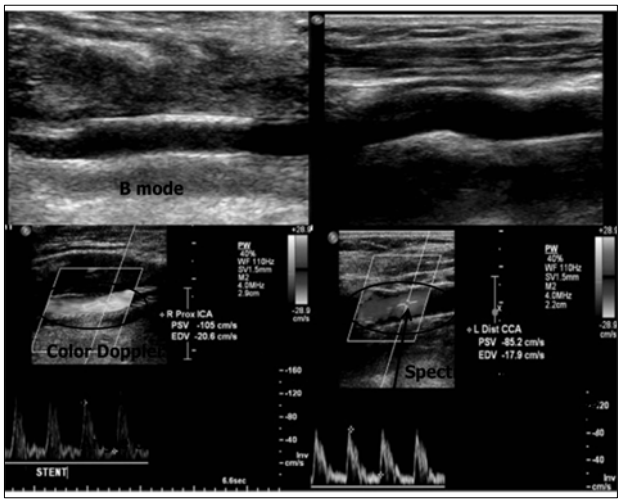
CONTENTS

1. B mode / Color flow
   - CCA carotid IMT
   - Luminal diameter
   - Carotid plaque: location, surface, echo
2. Spectral Doppler
   - Multiparametric approach
   - Flow velocity measurement:
     - Angle of insonation / angle correction
3. Closing

CDUS: 2-step, or duplex, procedure

- Imaging
  - Brightness-mode (B-mode) – gray scale
  - Color-Doppler or color-flow
- Spectral-Doppler
  - Blood flow velocity
  - Signal: both visual and auditory
  - Signal has peaks and ebbs (systolic and diastolic)



Brightness or color Doppler image

Intima-media thickness

Plaque

Intima, media, and IMT

Normal artery

- Intima : media (m) = 2.5 : 97.5 (%)
  - Median intima thickness, 0.02 mm

Diseased (thickened) artery

- **Intima** : media (m)= 20 : 80 (%) ----- 10 times

Plaque formation

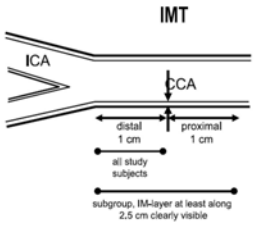
- **Intima** : media (M) = **MAJOR** : minor

Intima-media thickness (IMT)

- A '**double-line**' pattern:

the first echogenic interface on the far wall; *lumen-intima* interface,

the second; *the media-adventitia* interface.



Schmidt-Trucksass A., et al., Atherosclerosis 2003;166:57-65

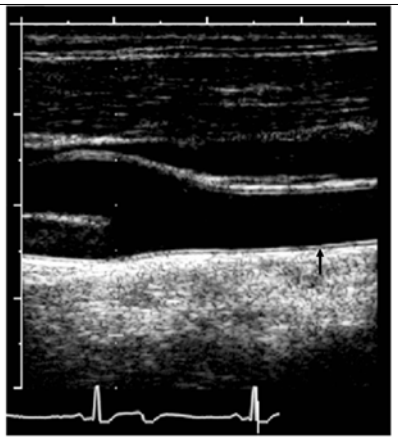


Figure 3 True longitudinal plane simultaneously demonstrating double lines on the near and far walls of the common carotid artery ("double-line" sign).

Instrumentation

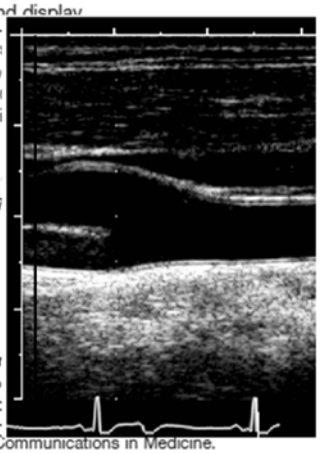
Table 4 Instrumentation and display

State-of-the-art ultrasound sy:
- Digital image acquisition an
- Phantom scans every 6 mo
- Semiannual routine preventi

Transducer
- Linear array
- Minimal compression (<10:
- Fundamental frequency ≥ 7
- Footprint ≥ 3 cm

Display
- Depth 4 cm
- Single focal zone
- Frame rate ≥ 25 Hz
- High dynamic range
- Clear 3-lead electrocardiogr
- Annotate images to describ

Carefully adhere to predefinec



DICOM, Digital Imaging and Communications in Medicine.

Probe orientation

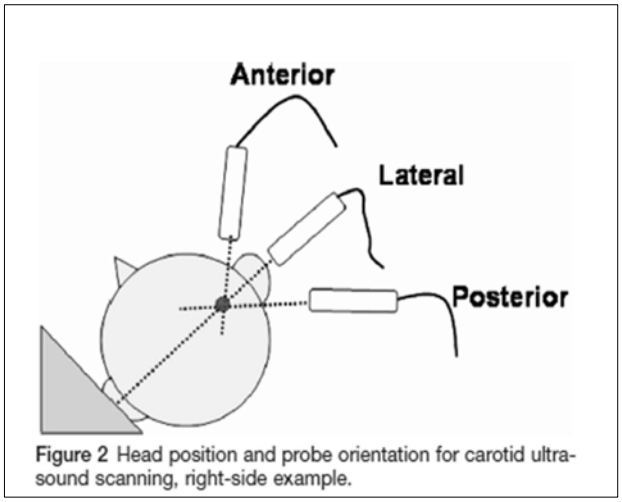
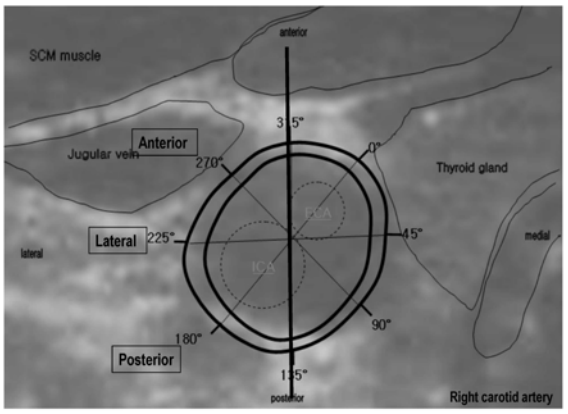
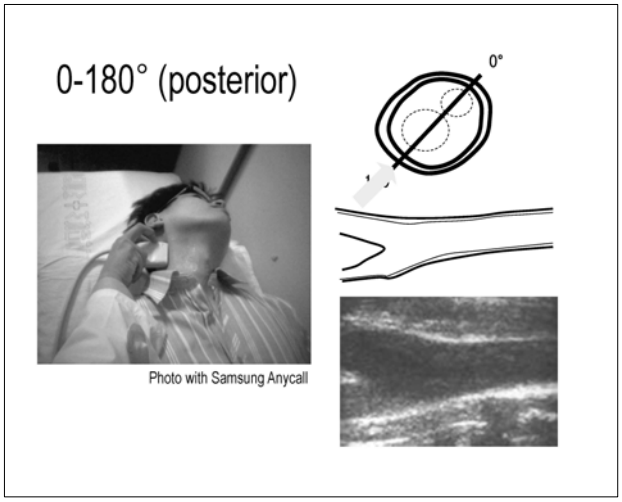
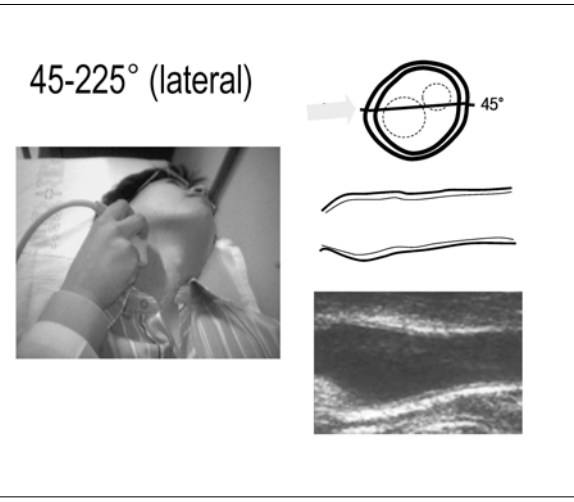


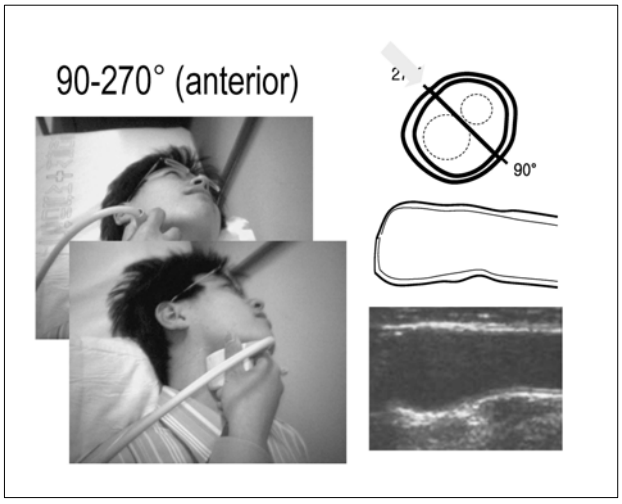
Figure 2 Head position and probe orientation for carotid ultrasound scanning, right-side example.



Lee JS, Jeong SK. JKNA 2007







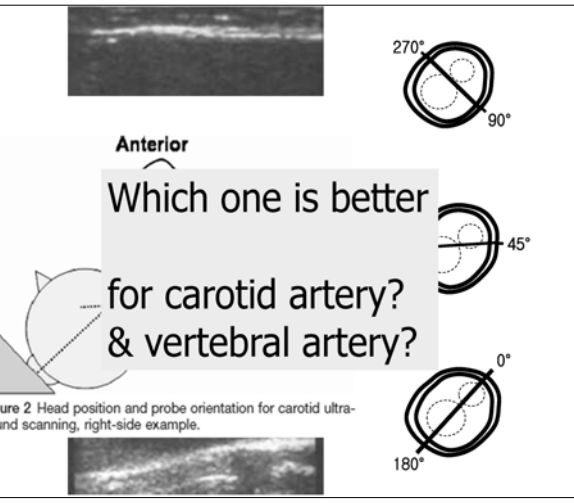
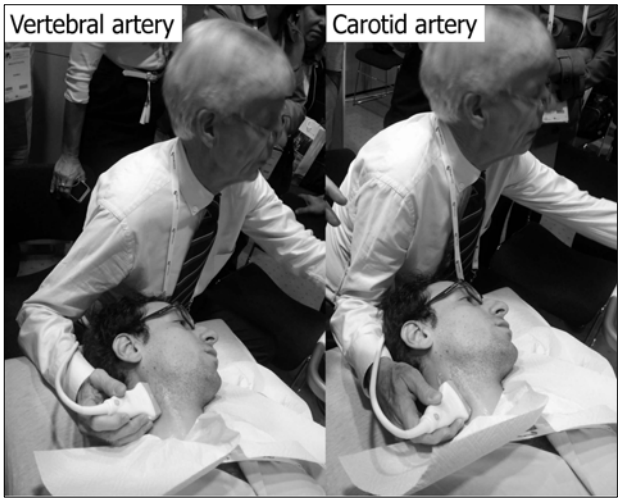
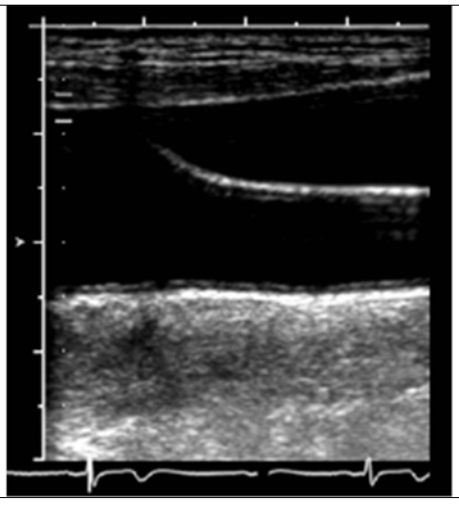


Figure 2 Head position and probe orientation for carotid ultrasound scanning, right-side example.



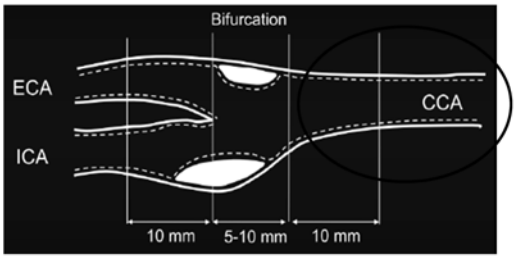
Gain setting



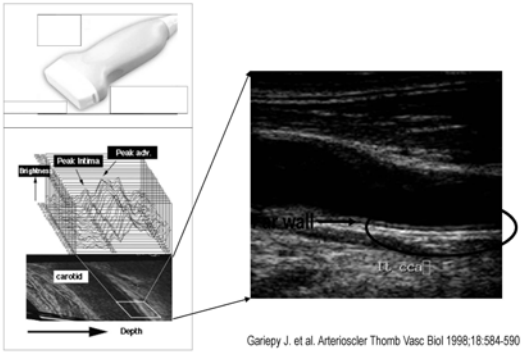
IMT measurement

Level

- **Common carotid artery**
- Carotid bulb
- ICA (ICA bulb portion, distal ICA)



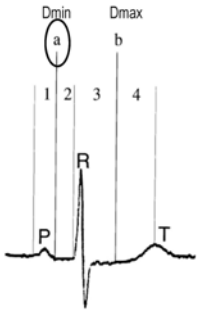
Far wall, distal CCA



Gariepy J. et al. Arterioscler Thromb Vasc Biol 1998;18:584-590

End-diastolic phase (R wave)

- End-diastolic phase > peak systolic (about 5%)
- Reduce variability
- The less arterial diameter, the more IMT
- P-R interval mid-way (a) → QRS (R)



Selzer RH, et al. *Atherosclerosis.* 2001;154:185-193

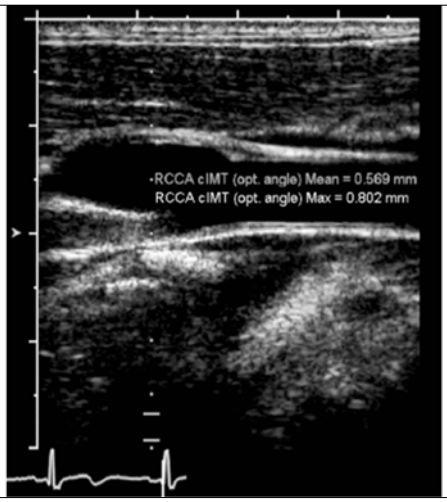
IMT measurement: (Precision, reproducibility)

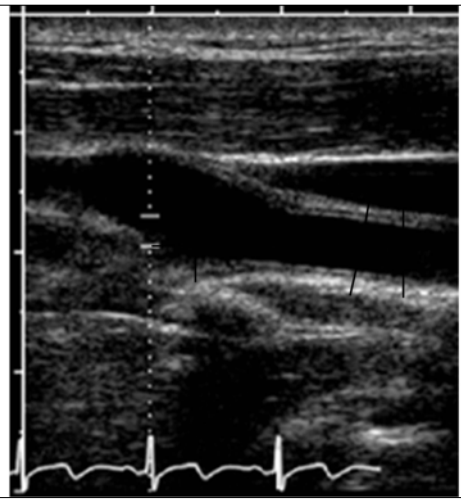
- Hand measurement (An outsider group)

Howard G, et al. ARIC study Stroke 1993;24:1297-1304

- Computer assisted measurement: higher reliability coefficient (R > 0.99)

Graf S, et al. Ultrasound Med Biol 1999;25:1353-1363
Salonen JT, et al. Lancet 1993;341:1158-1159

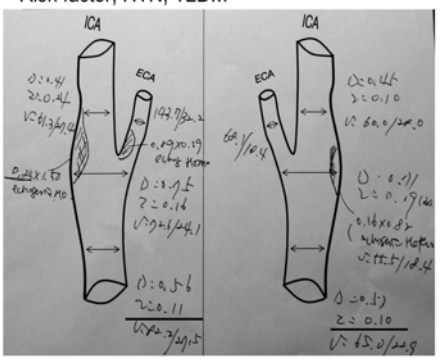




Case

- 67, man
- CC; TIA
- Risk factor; HTN, T2DM
- Carotid IMT
- Right CCA;

- 67, man with transient right hemiparesis
- Risk factor; HTN, T2DM



>95% tile 90-95% tile

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Normative and mean carotid intima-media thickness values according to metabolic syndrome in Koreans: The Namwon Study

Table 3
Mean CCA-IMT (mm) values according to age group among the healthy reference population.[a]

	No.	Mean (SD)	95% CI	Range	Percentile						
					5	10	25	50	75	90	95
Males[b]											
45–49 years	61	0.614 (0.093)	0.590–0.637	0.455–0.917	0.468	0.506	0.545	0.598	0.687	0.733	0.754
50–54 years	75	0.671 (0.107)	0.650–0.695	0.500–0.984	0.509	0.546	0.591	0.653	0.733	0.823	0.877
55–59 years	126	0.711 (0.135)	0.687–0.735	0.460–1.462	0.549	0.571	0.603	0.688	0.778	0.867	0.924
60–64 years	129	0.759 (0.118)	0.738–0.779	0.545–1.281	0.596	0.636	0.682	0.733	0.821	0.911	1.005
65–69 years	157	0.783 (0.141)	0.761–0.805	0.477–1.286	0.594	0.604	0.688	0.776	0.868	0.933	1.056
70–74 years	165	0.787 (0.123)	0.768–0.806	0.522–1.341	0.585	0.643	0.708	0.778	0.865	0.959	1.002
Sub-total	713	0.740 (0.136)	0.730–0.750	0.455–1.462	0.549	0.590	0.643	0.730	0.821	0.914	0.964
Females[b]											
45–49 years	329	0.613 (0.101)	0.602–0.624	0.415–1.244	0.464	0.504	0.549	0.598	0.662	0.733	0.803
50–54 years	324	0.653 (0.116)	0.640–0.665	0.434–1.371	0.505	0.509	0.575	0.640	0.699	0.782	0.867
55–59 years	299	0.689 (0.107)	0.676–0.701	0.460–1.100	0.509	0.550	0.598	0.685	0.734	0.823	0.869
60–64 years	356	0.718 (0.103)	0.707–0.728	0.480–1.096	0.553	0.595	0.643	0.698	0.778	0.863	0.912
65–69 years	375	0.753 (0.114)	0.741–0.765	0.460–1.196	0.594	0.617	0.685	0.733	0.823	0.914	0.959
70–74 years	199	0.778 (0.122)	0.761–0.795	0.505–1.344	0.595	0.640	0.688	0.775	0.832	0.957	1.004
Sub-total	1882	0.697 (0.123)	0.691–0.702	0.415–1.371	0.509	0.549	0.598	0.688	0.778	0.864	0.914

Carotid plaque

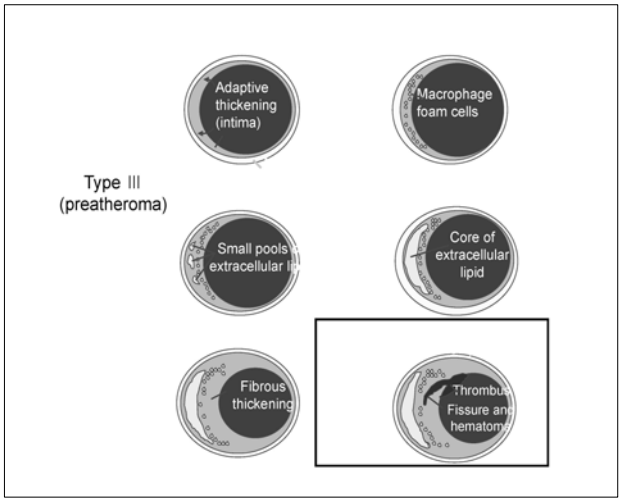
- A definition of plaque:
- Classification of carotid plaque

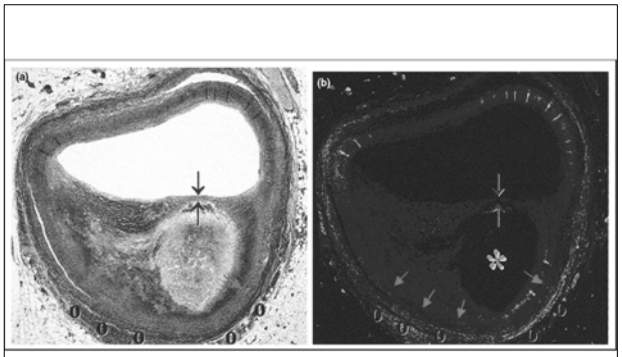
Plaque ≈ Atherosclerosis

- Arteriosclerosis:
  - a chronic disease in which thickening, hardening, and loss of elasticity of the arterial walls result in impaired blood circulation.
  - Aging, hypertension, diabetes, hyperlipidemia, and etc.
- Atherosclerosis: focal ! **intima !!!**
  - a form of arteriosclerosis characterized by the deposition of atheromatous plaques containing cholesterol and lipid in the innermost layer of the walls of large and medium-sized arteries.

A process of atherosclerosis

- Type
  1. Adaptive thickening of intima
  2. Macrophage foam cell
  3. Extracellular lipid pool
  4. **Core of the extracellular lipid**
  5. Fibrous thickening
  6. **Plaque fissure and thrombus formation**





The average advanced atherosclerotic plaque contains 68% fibrous tissue, 24% lipid (**16% necrotic core**, 7% free cholesterol and 1% foam cells) and 8% calcium.

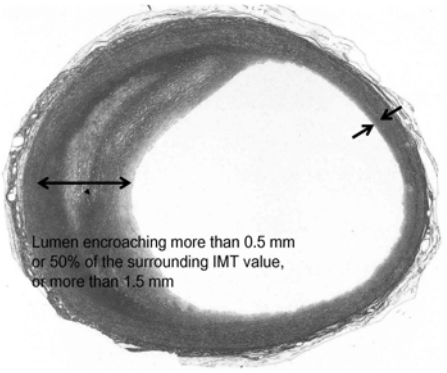
Ruptured plaques (formerly vulnerable) contain proportionally **more necrotic core (>40% of plaque volume**). Vulnerable plaques tend to be **outwardly remodeled with a relatively large plaque burden** measured pathologically (50-75% of cross-sectional arterial area).

Definition: carotid plaque by US

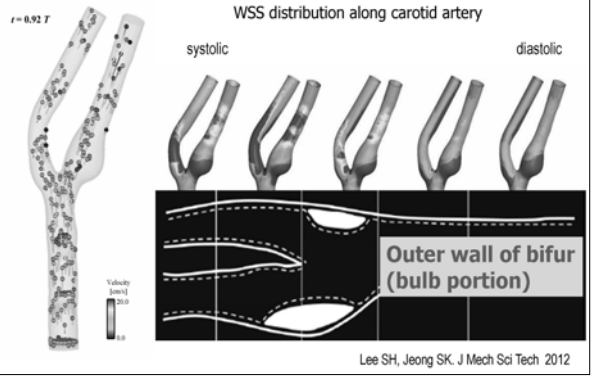
- Carotid plaque
  - Focal structure encroaching the lumen of at least 0.5 mm
  - or 50% of the surrounding IMT value
  - or a thickness > 1.5 mm

Touboul PJ, et al. Cerebrovasc Dis 20012

Atheromatous plaque

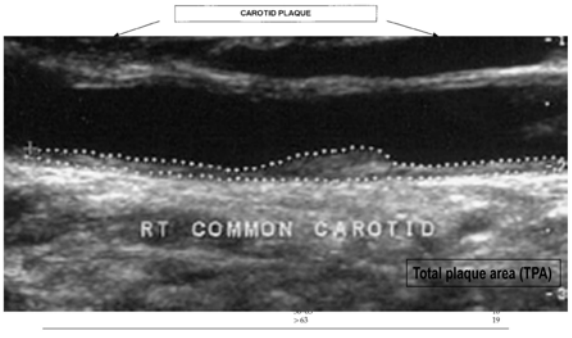


Plaque은 어디에?



Lee SH, Jeong SK. J Mech Sci Tech 2012

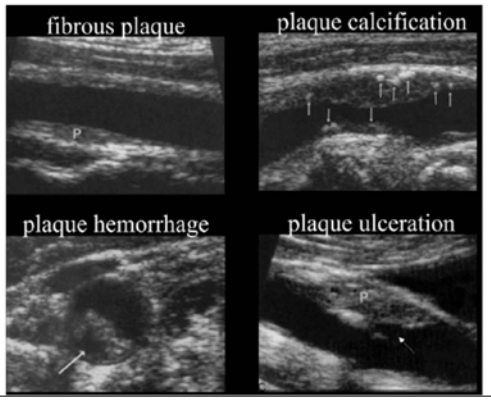
Carotid plaque measurement?



Carotid plaque with B-mode

- Plaque echogenicity (vs. SCM)
  - Echolucent: lipid, hemorrhage, thrombus
  - Dominantly echolucent
  - Dominantly echorich (or echogenic)
  - Echorich: fibrosis, calcification
- Homogenous vs. heterogenous
- Surface regularity: ulcerated

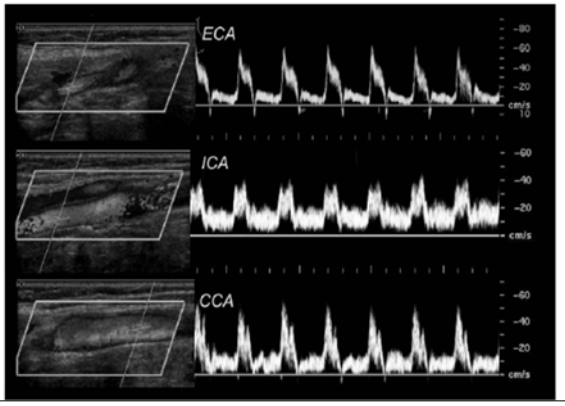
Carotid plaque with B-mode



Spectral Doppler

Blood flow velocity
ICA stenosis

Normal carotid waveforms

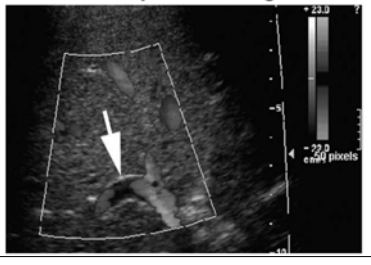


Measurement of BFV (freq)

Aliasing
Angle of insonation / angle correction
Velocity cursor placement
Doppler gain
Irregular heart beats

Angle of insonation

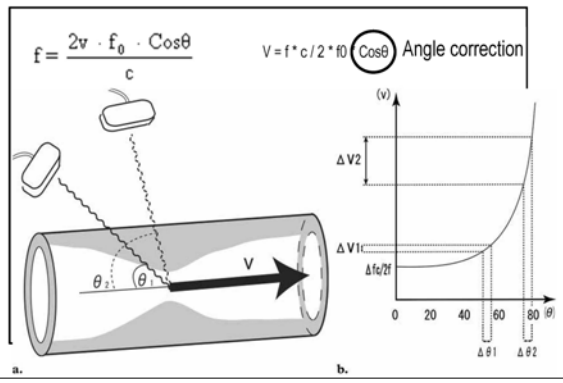
- The angle between the transducer and the vessel being studied
- Should be **with the smallest possible angle** of insonation

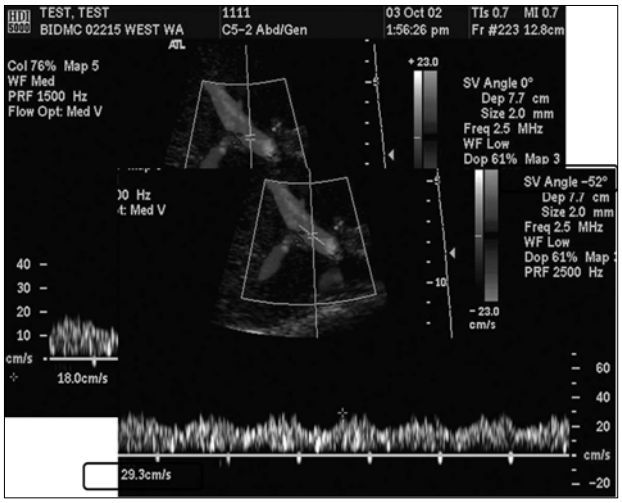


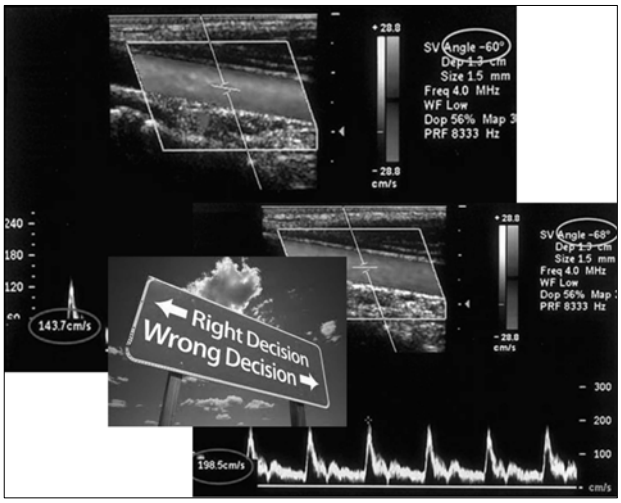
Angle correction

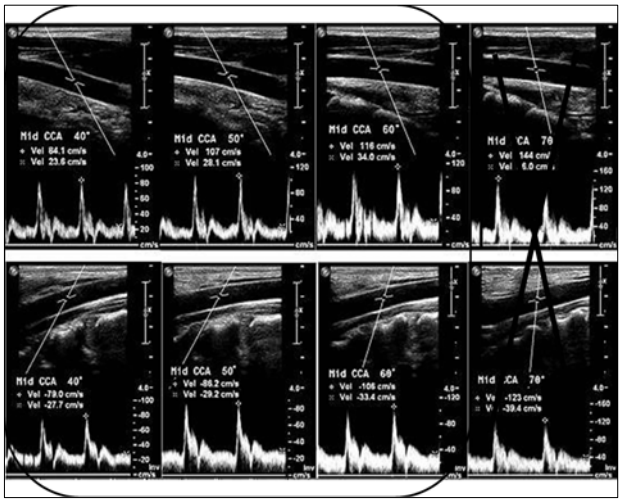
- Adjustment of the Doppler angle and is used to calibrate the velocity scale for the angle between the US bean and the blood flow being measured
  - Doppler shift frequency → velocity scale
- The true Doppler angle by placing the cursor parallel to the direction of blood flow
- Ideally, 40º-60º angle relative to the transducer

Small incident angle of 60 or less is essential

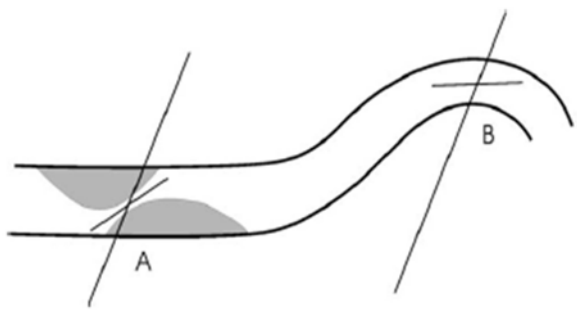








Angle of insonation → angle correction



Spectral Doppler help diagnose
ICA stenosis and its grading?

Diagnosis of ICA stenosis

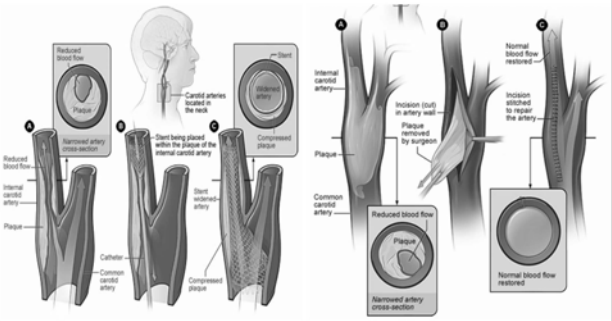


Table 14. Summary of Recommendations Regarding the Selection of Revascularization Techniques for Patients With Carotid Artery Stenosis

	Symptomatic Patients		Asymptomatic Patients:
	50% to 69% Stenosis	70% to 99% Stenosis*	70% to 99% Stenosis*
Endarterectomy	Class I LOE: B	Class I LOE: A	Class IIa LOE: A
Stenting	Class I LOE: B	Class I LOE: B	Class IIb LOE: B

The severity of stenosis is defined according to angiographic criteria by the method used in NASCET[70] but generally corresponds as well to assessment by sonography[136] and other accepted methods of measurement. See Section 7.2 to 7.4.4 for details.

LOE indicates level of evidence.

Brott TG, et al. Stroke. 2011 Apr[illegible] Stroke 2011

ICA Stenosis scale -- angiography

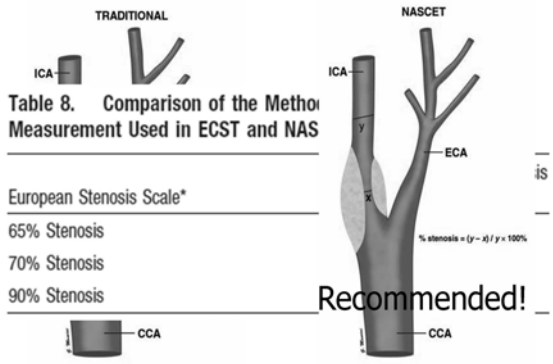


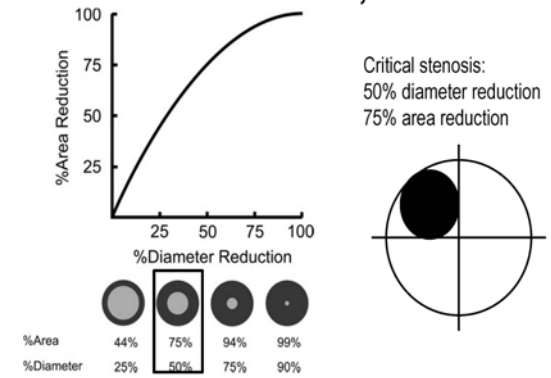
Table 8. Comparison of the Metho
Measurement Used in ECST and NAS

European Stenosis Scale*
65% Stenosis
70% Stenosis
90% Stenosis

is

Recommended!

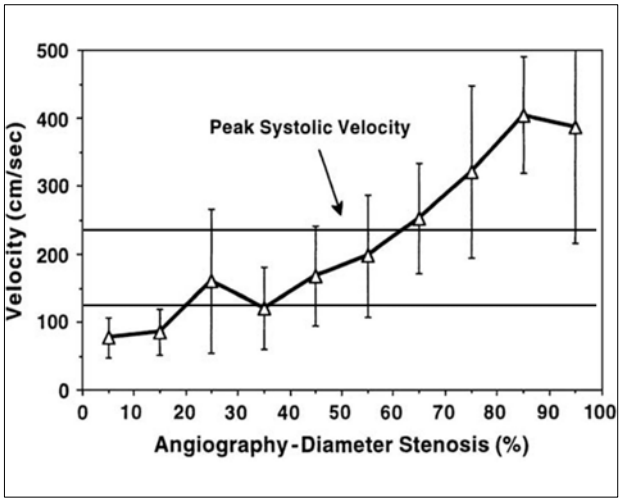
Stenosis = diameter (or area) reduction
≈ BFV increase, 2-3 times



Critical stenosis:
50% diameter reduction
75% area reduction

Spectral Doppler help diagnose
ICA stenosis and its grading

with changes of flow velocity!



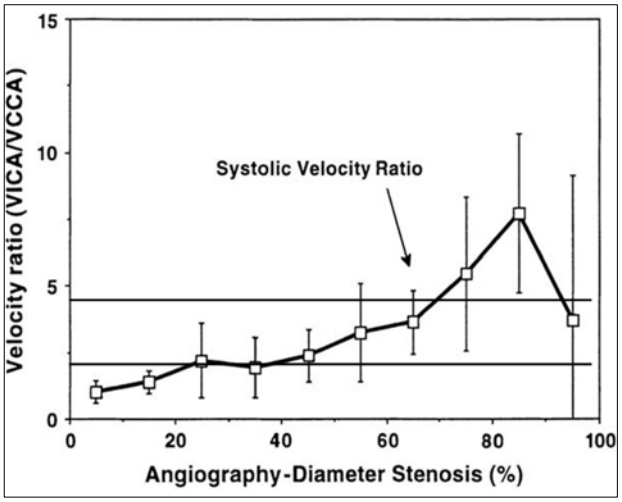


TABLE 3
Consensus Panel Gray-Scale and Doppler US Criteria for Diagnosis of ICA Stenosis

	Primary Parameters		Additional Parameters	
Degree of Stenosis (%)	ICA PSV (cm/sec)	Plaque Estimate (%)*	ICA/CCA PSV Ratio	ICA EDV (cm/sec)
Normal	<125	None	<2.0	<40
<50	<125	<50	<2.0	<40
50–69	125–230	≥50	2.0–4.0	40–100
≥70 but less than near occlusion	>230	≥50	>4.0	>100
Near occlusion	High, low, or undetectable	Visible	Variable	Variable
Total occlusion	Undetectable	Visible, no detectable lumen	Not applicable	Not applicable

* Plaque estimate (diameter reduction) with gray-scale and color Doppler US.

Grant EG, et al. Radiology 2003

5. Closing

Feel comfortable while dong CDUS!

Summary I

- B mode for carotid IMT
  - Definition of carotid IMT
  - Depth 4 cm
  - 3 Probe orientations: anterior/lateral/posterior
    --- postero(lateral) for pressure minimization
  - Cardiac gating (R wave)
- B mode for carotid plaque
  - Plaque description and classification
  - Diameter

Summary II

- Spectral Doppler
  - ICA stenosis (NASCET criteria)
  - Multiparametric approach including ICA PSV
  - 125 – 230 cm/s, 2 – 4, 40 – 100 cm/s
- Blood flow velocity measurement
  - Angle of insonation / correction
  - Velocity cursor placement, Doppler gain
  - Irregular heart beats

References 1

- Lee YH, Shin MH, Kweon SS, Nam HS, Park KS, Choi JS, Choi SW, Kim HY, Oh GJ, Ahn HR, Oh HS, Jeong SK. Normative and mean carotid intima-media thickness values according to metabolic syndrome in Koreans: The namwon study. *Atherosclerosis*. 2014;234:230-236.
- von Reutern GM, Goertler MW, Bornstein NM, Del Sette M, Evans DH, Hetzel A, et al. Grading carotid stenosis using ultrasonic methods. *Stroke 2012;43:916-921.*
- Beach KW, Bergelin RO, Leotta DF, *et al. Standardized ultrasound evaluation of carotid stenosis for clinical trials: University of Washington Ultrasound Reading Center. Cardiovasc Ultrasound 2010, 8:39.*
- Gaitini D, Soudack M. Diagnosing carotid stenosis by Doppler sonography: state of the art. J Ultrasound Med 2005, 24:1127-1136.

References 2

- Grant EG, Benson CB, Moneta GL, *et al. Carotid artery stenosis: gray-scale and Doppler US diagnosis--Society of Radiologists in Ultrasound Consensus Conference. Radiology 2003, 229:340-346.*
- Jaff MR, Goldmakher GV, Lev MH, Romero JM. Imaging of the carotid arteries: the role of duplex ultrasonography, magnetic resonance arteriography, and computerized tomographic arteriography. Vasc Med 2008, 13:281-292.
- Yan BP, Clark DJ, Jaff MR, *et al. Carotid duplex ultrasound velocity measurements versus intravascular ultrasound in detecting carotid in-stent restenosis. Circ Cardiovasc Interv 2009, 2:438-443.*