EUROPEAN SOCIETY OF NEUROSONOLOGY
AND CEREBRAL HEMODYNAMICS

ean
the home of neurology

5th Congress of the European Academy of Neurology

Oslo, Norway, June 29 - July 2, 2019

Hands-on Course 13

EAN/ESNCH: Neurosonology – from basics to clinical applications (Level 1-2)

Cervical artery protocol and plaque morphology

Branko Malojcic
Zagreb, Croatia

Email: bmalojcic@gmail.com

CERVICAL ARTERY ULTRASOUND PROTOCOL AND PLAQUE MORPHOLOGY

Branko Malojcic, MD, PhD, FESO, FWSO
TIA Center
Dpt. Of Neurology
University Hospital Cener Zagreb, Croatia

Conflict of Interest

In relation to this presentation and manuscript:

❑ the Author has no conflict of interest in relation to this manuscript.

Basics of cervical artery ultrasound

Comparison of methods

	DSA	CE-MRA	CTA	DUS
Stenosis assessment accuracy	Gold standard	Sensitivity 0.94 Specificity 0.93	Sensitivity 0.77 Specificity 0.94	Sensitivity 0.89 Specificity 0.84
Stenosis morphology	Excellent	Good	Good	Limited
Plaque composition	Limited	Additional sequences needed	Good	Good
Aortic arch visibility	Good	Good	Good	Limited
Intracranial circulation	Good	Good	Good	Additional transcranial Doppler US needed
Invasiveness	Yes	Minimal	Minimal	No
Radiation	Yes	No	Yes	No
Contrast agent	Yes	Yes	Yes	No

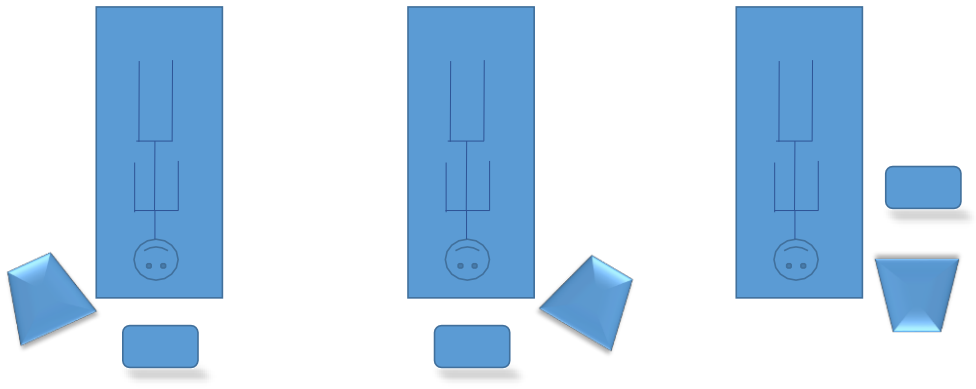
Abbreviations: CTA, computed tomography angiography; DSA, digital subtraction angiography; DUS, duplex ultrasound.
Note: Sensitivity and specificity is for 70 to 90% stenosis and based on the meta-analysis from Wardlaw et al.[13]

Adla et al. Int J Angiol. 2015 Sep; 24(3): 179–184.

Operator-dependency can be minimized

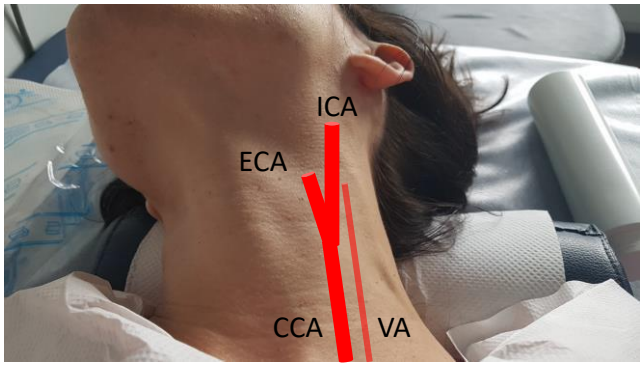
- Training
- Experience
- Certification (physician and sonographer)
- Quality control, lab accreditation
- CME

Work space setup



a) b) c)

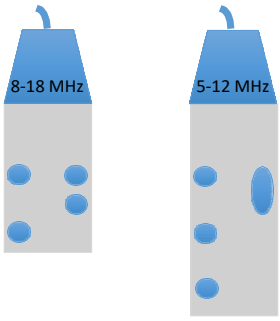
Patient positioning



45° away from the examined artery
Neck muscles relaxed
Pillow (avoid hyperextension)

Selection of linear probes

- Higher frequency = higher resolution
  = shallower penetration

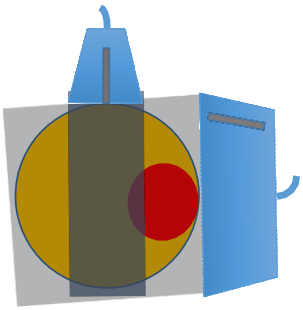


Cervical artery examination protocol

B-mode (grayscale) imaging

- Morphology
- Anatomy
- Atherosclerotic changes

Insonation planes



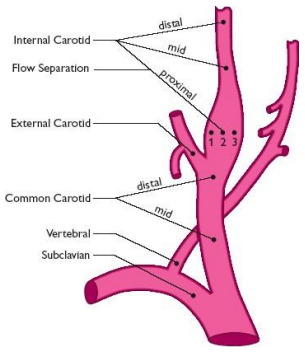
Transverse

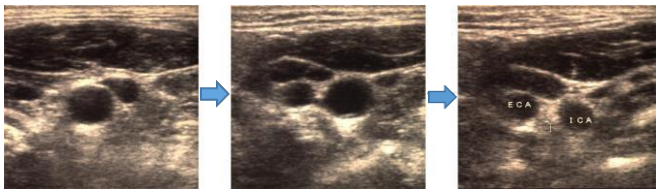
Longitudinal

Longitudinal

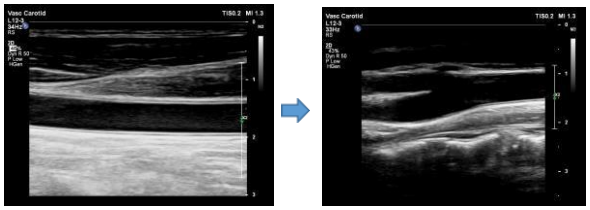
Examination of carotid arteries

1. B-mode - morphology





Transverse

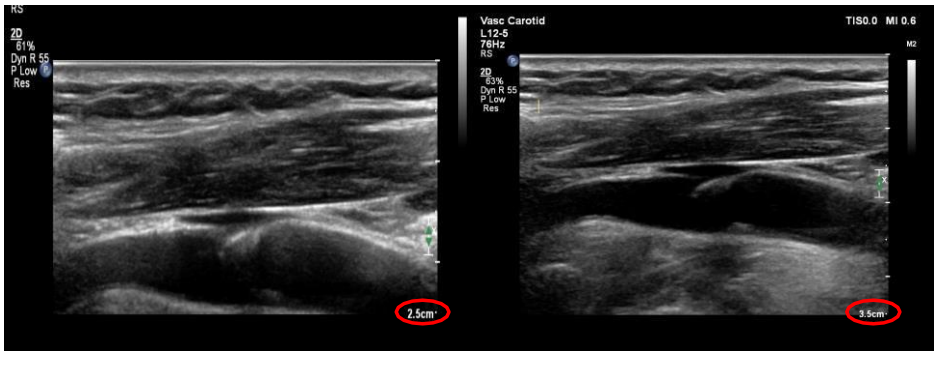


Longitudinal

Depth / Image size

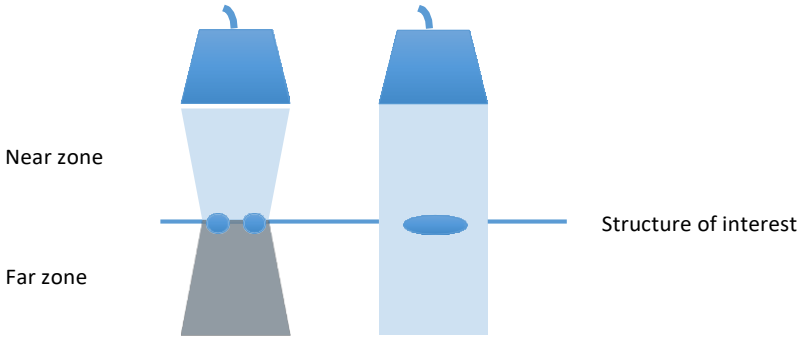
- Start deeper
- Put the area of interest at ¾ of screen depth
- Too deep picture reduces temporal resolution (frame rate)

Depth / Image size

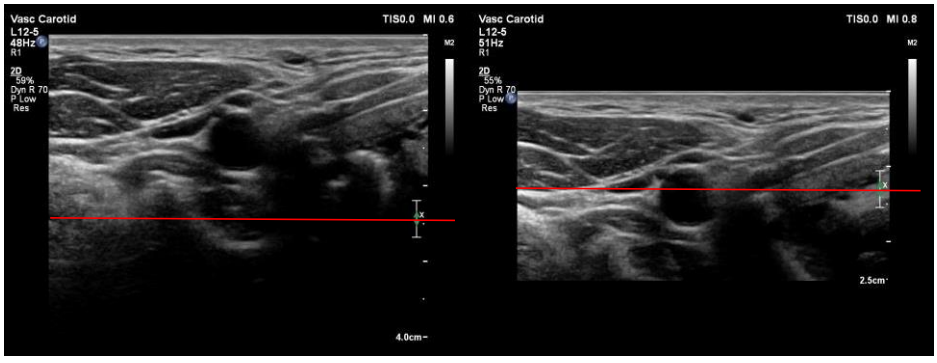


Focus

- Best lateral resolution at the focal zone



Which focus is optimised for CCA?



Gain

- Compensates for attenuation
- Brightens the image
- Amplifies returning signals

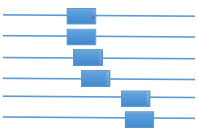
Gain

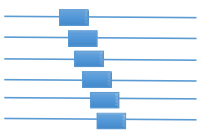
- Too much gain increases intensity of artifacts and makes details invisible
- Optimal gain = most details visible
- Vessel lumen black
- Vessel wall sharply delineated

Which gain is optimised?

✓

Time Gain Compensation



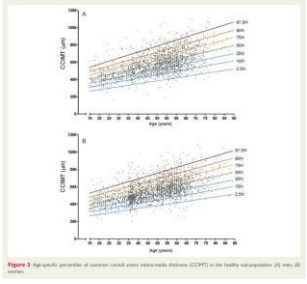


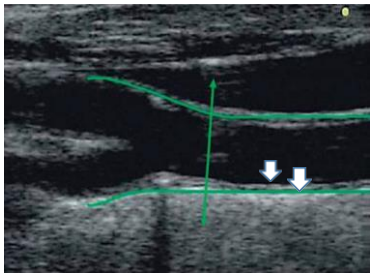
Time Gain Compensation

- Selective amplification of weaker signals
- Optimal TGC = smooth B-mode picture
- Avoid sharp transition from one to another TGC slider

IMT – early atherosclerosis

- Mannheim protocol
  - far wall of the vessel
- common carotid IMT
  - 10 mm below it's end
- carotid bifurcation IMT





- automated edge detection system – mean values from two measurements

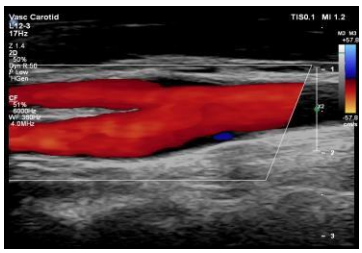
Touboul P-J. et al. "Mannheim carotid intima-media thickness and plaque consensus (2004–2006–2011)." Cerebrovascular diseases 34.4 (2012): 290-296
Engelen L. et al. "Reference intervals for common carotid intima-media thickness measured with echotracking" European heart journal 34.30 (2012): 2368-2380.

Color Doppler imaging

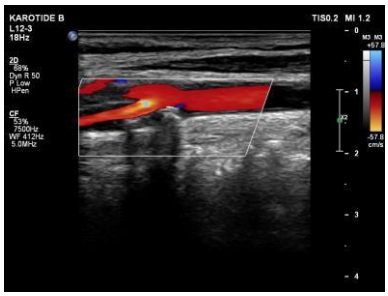
- Detection of blood flow
- Direction of blood flow
- Turbulence

Color Doppler imaging

Laminar flow



Aliasing

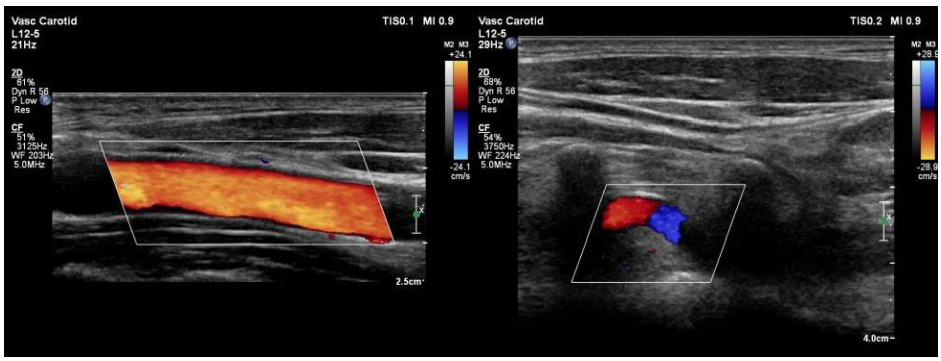


Reversal of flow

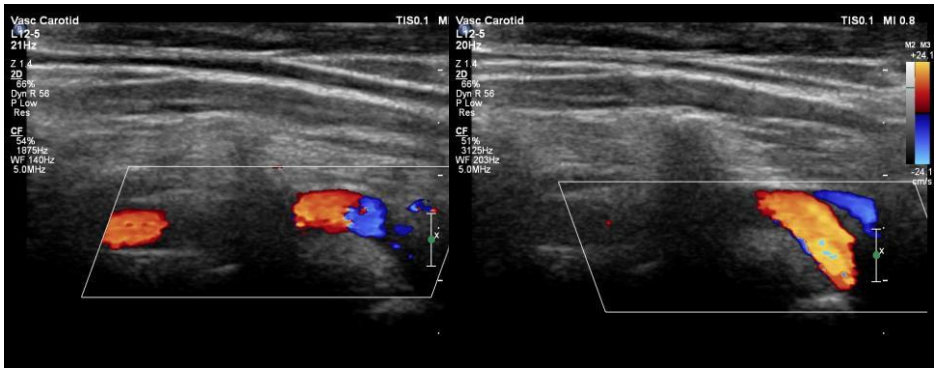
Color Box

- Smallest possible size for the best frame rate
- Steering the color box to analize the vessel in the full lenght
- Steering the color box to obtain stronger doppler signal

Color Box Size



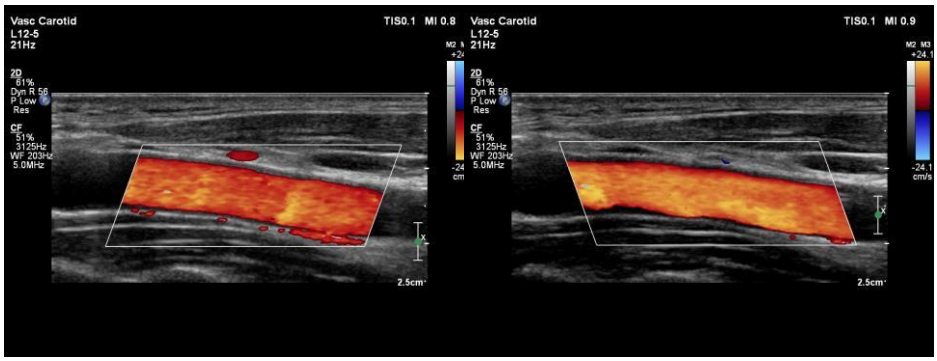
Color Box Steering



Color Gain

- Too much gain can give “bleeding” artifacts
- If no color appears, try lower frequency probe (penetration) as lateral resolution is not that important in color mode

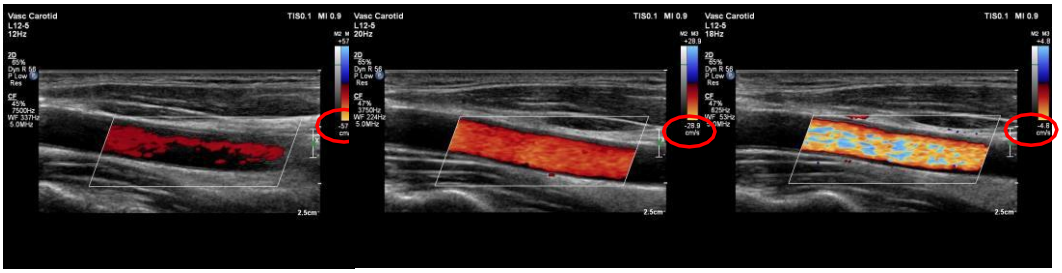
Colour gain



Color PRF

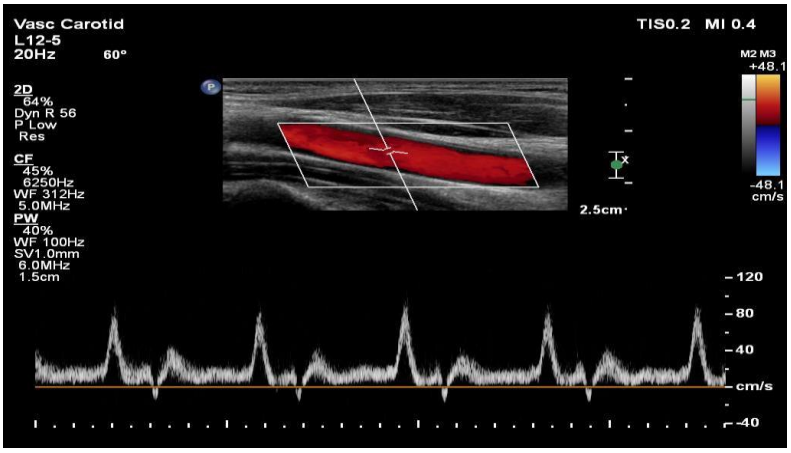
- Increase PRF if color aliasing appears
- Insonate at the shallower depth if aliasing appears
- Decrease PRF if no visible color (and the flow is expected)

Color PRF



PW Doppler

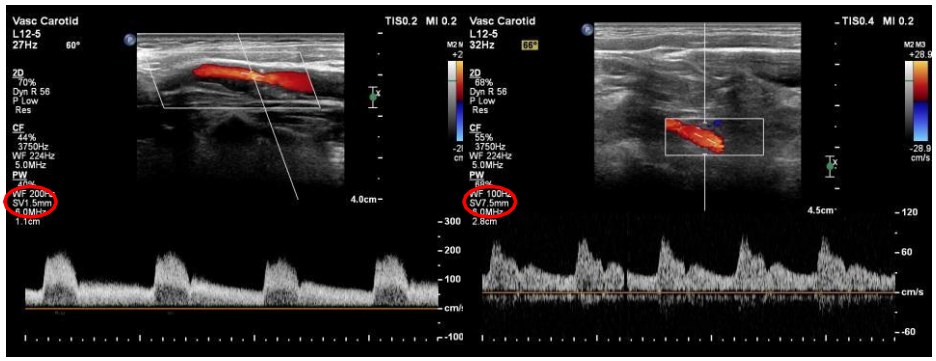
- Sample
- Angle correction
- Spectral analysis



Sample Volume / Gate

- Focuses pulsed wave on an area of interest
- Large sample volume can pick the signal of surrounding vessels
- Small sample volume if blood flow in stenosis has to be investigated

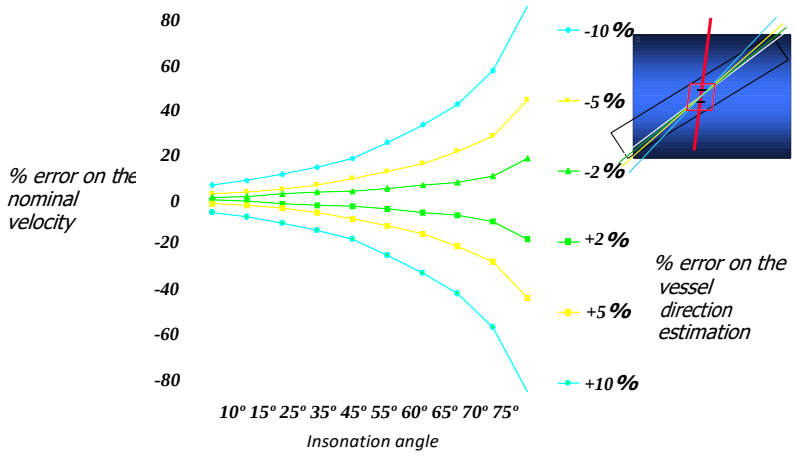
Sample Volume / Gate



Angle

- Corrects the angle of ultrasound beam when the line of interrogation is not parallel to the line of blood flow
- Avoid insonation angle bias on velocity

Insonation Angle Bias On Velocity



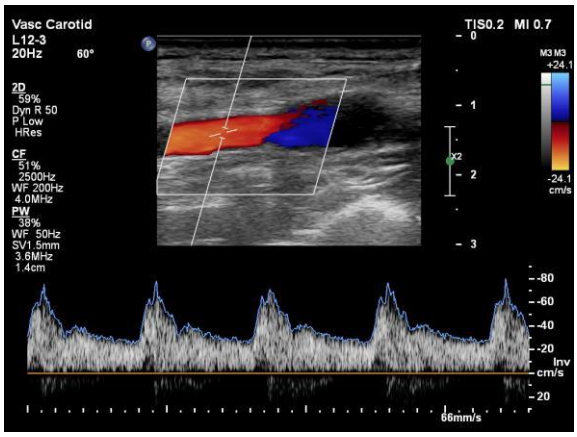
Pulse Repetition Frequency

- Also called “Scale”
- Prevents aliasing
- Enable optimal scale range for the analysis of the whole spectrum
- Initial PRF defined in presets

Pulse Repetition Frequency

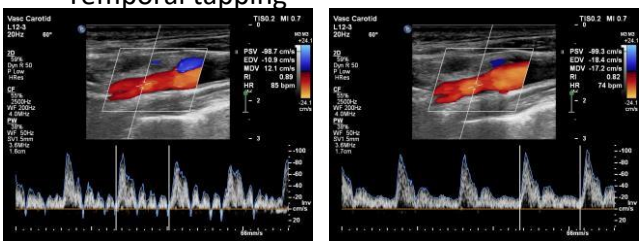
PW parameters

- Flow direction
- Mean blood flow velocity (MBFV)
- Peak systolic velocity (PSV)
- End diastolic velocity (EDV)
- Pulsatility and resistance indexes (PI, RI)



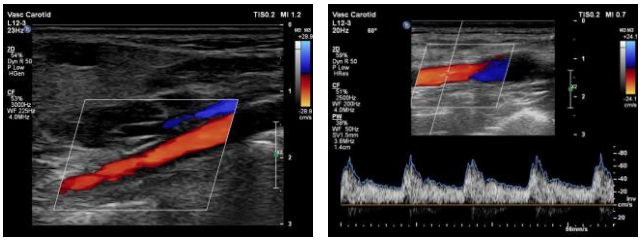
Examination of carotid arteries

Temporal tapping



ECA

1. Color – hemodynamics
2. PW – spectral analysis

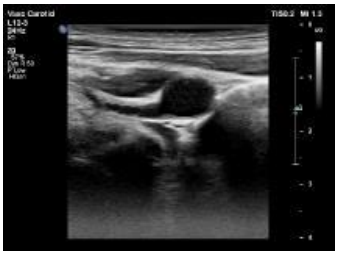


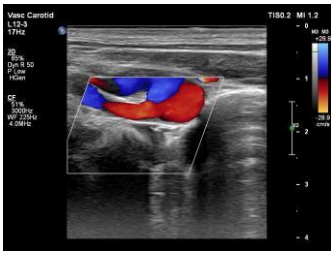
ICA

CCA

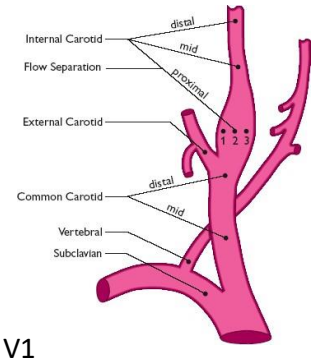
Examination of vertebral arteries

V2

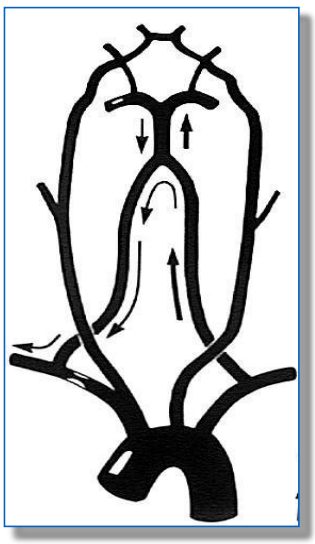


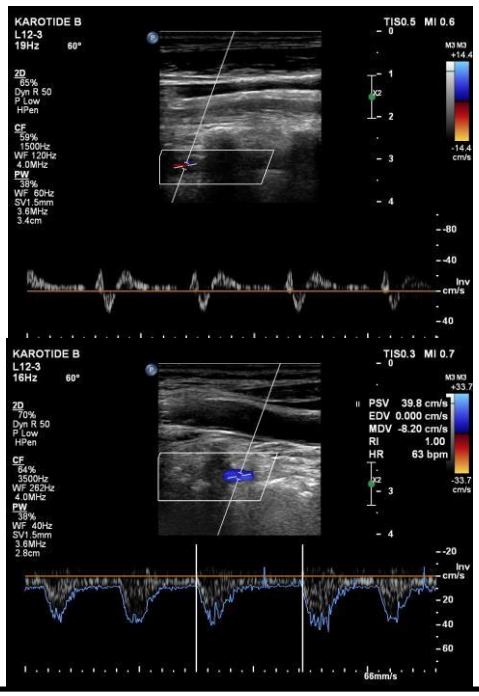


V0, V1



What's the diagnosis?



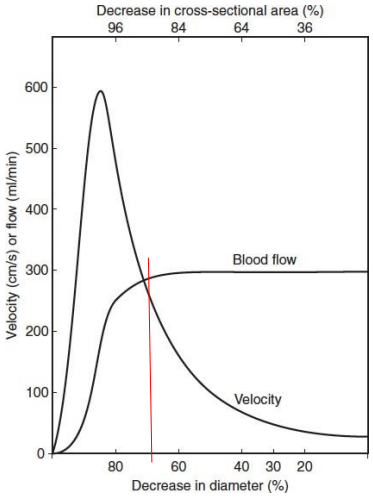


Degree of stenosis

Estimating the degree of stenosis

- Morphology (B-mode)
- Blood flow velocity (PW)

Estimating the degree of stenosis



>70% of diameter reduction limits blood flow
⇒significant stenosis

Measurement of BFV is the most reliable parameter for estimating the degree of stenosis

Take care:
- Long lesions
- Tandem lesions
- Contralateral disease

Spencer and Reid. Stroke 1979;10(3):326-30.

Degree of ICA Stenosis in Doppler US*

Consensus Criteria – NASCET criteria

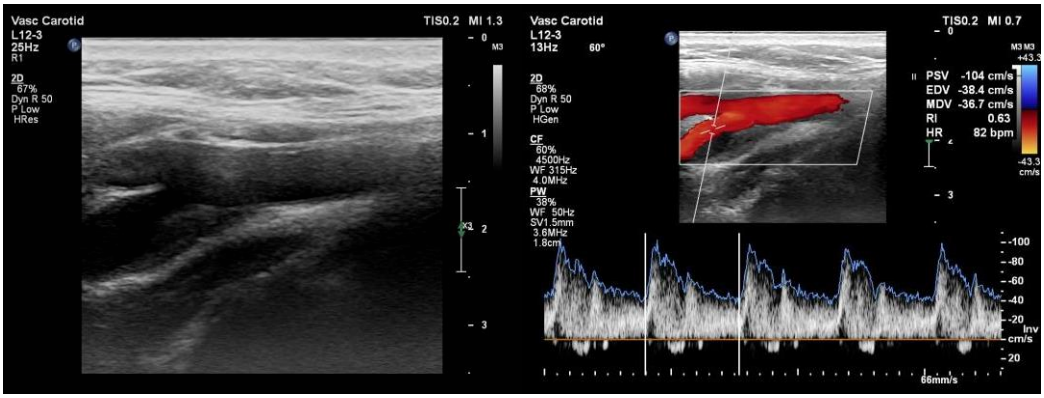
ICA stenosis (%)	ICA PSV cm/sec	ICA EDV cm/sec	PSV ratio ICA/CCA	Plaque
Normal	< 125	< 40	< 2.0	None
< 50%	< 125	< 40	< 2.0	< 50%
50 – 69%	125 – 230	40 – 100	2.0 – 4.0	≥ 50%
> 70%	> 230	> 100	> 4.0	≥ 50%
Near occlusion	variable	variable	variable	visible
Total occlusion	undetectable	undetectable	NA	no lumen

* Diameter reduction

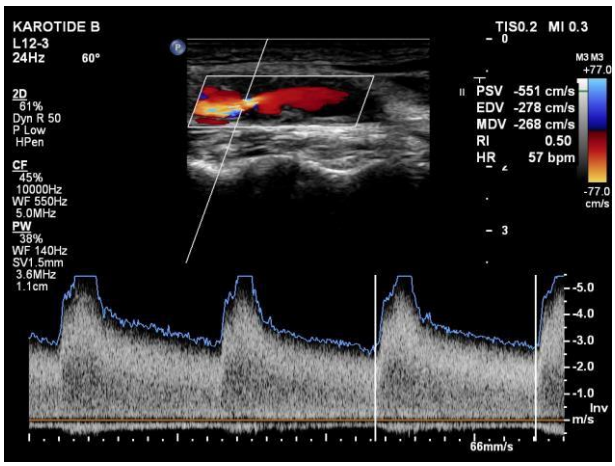
Grant EG et al. Radiology 2003 ; 229 : 340 – 346.

What's the degree of stenosis?

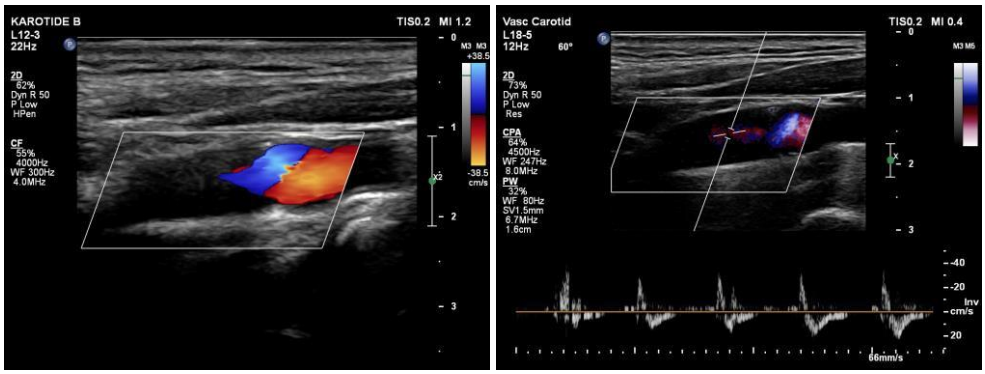
- Morphology
- Blood flow velocity



What's the degree of stenosis?



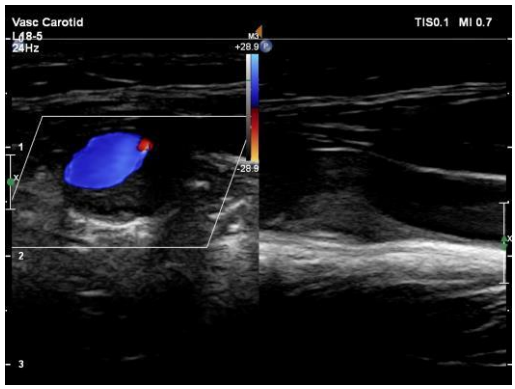
What's the degree of stenosis?



Plaque morphology

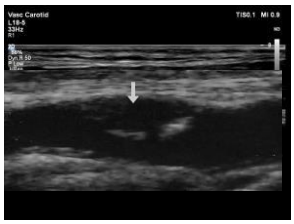
Plaque morphology

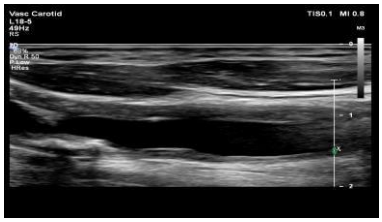
- Echolucency
- Surface
- Presence of ulceration



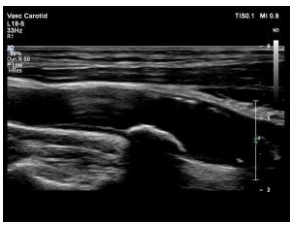
Plaque echolucency

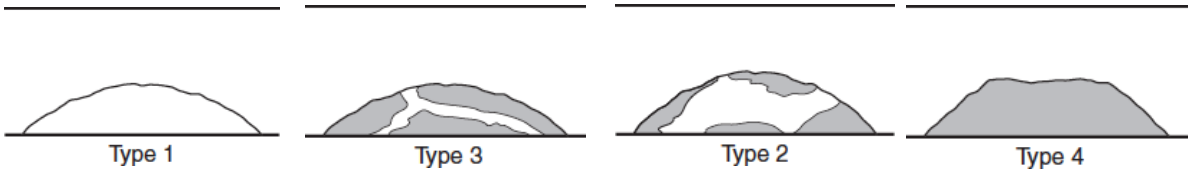
Anechoic





Echogenic

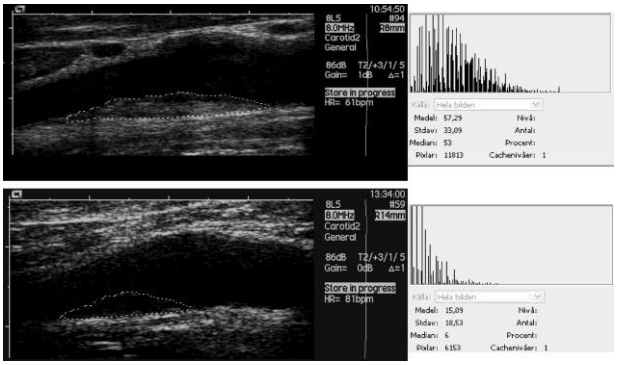




Bock and Lusby 1992

Gray scale median

- Risk of stroke
- Embolic risk
- Plaque evolution
- GSM cut-off 25



Stroke. 2007;38:2074–2078
J Cardiovasc Surg. 1988;29:676-681

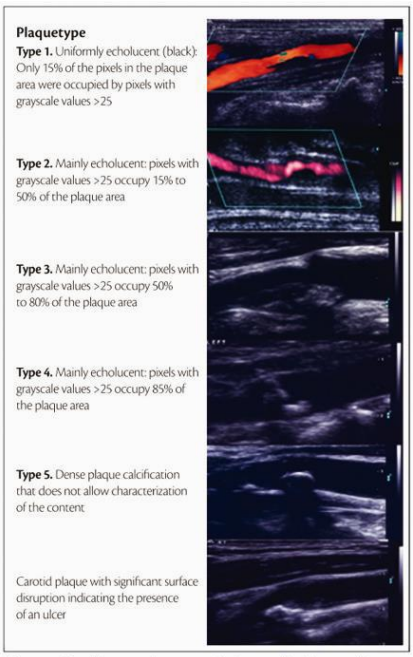


Figure 1. Carotid artery plaque morphology and its characteristics.

Table 1 Studies evaluating the association between carotid plaque echolucency and risk of ipsilateral stroke

Study (year)	Number of patients	Mean follow-up (months)	Ipsilateral stroke RR (95% CI)
O'Holleran *et al*[19] (1987)	293	46	5.12 (2.01 to 13.04)
Polak *et al*[20] (1998)	4886	39.6	1.96 (1.25 to 2.90)
Mathiesen *et al*[21] (2001)	177	36	3.85 (0.46 to 32.28)
Grønholdt *et al*[22] (2001)	111	52.8	0.87 (0.34 to 2.23)
Nicolaides *et al*[23] (2005)	1092	37.1	2.23 (1.28 to 3.87)
Topakian *et al*[24] (2011)	435	21.8	6.61 (1.42 to 30.75)
Silvestrini *et al*[25] (2013)	621	27*	2.37 (1.14 to 4.92)
Huibers *et al*[26] (2016)	814	60	2.52 (1.20 to 5.25)

*Median follow-up.
RR, relative risk.

Paraskevas KI, et al. Stroke and Vascular Neurology 2018;**3**.

Eur J Vasc Endovasc Surg (2018) 55, 3–81

esvs

Editor's Choice — Management of Atherosclerotic Carotid and Vertebral Artery Disease: 2017 Clinical Practice Guidelines of the European Society for Vascular Surgery (ESVS)

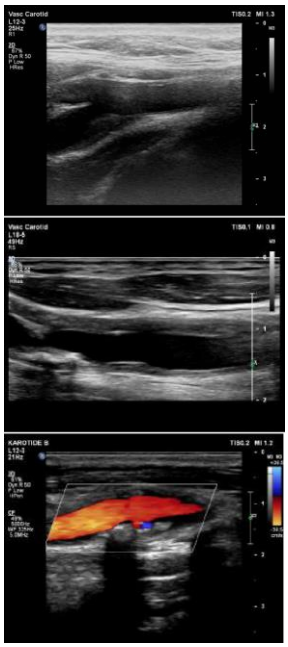
A.R. Naylor [a], J.-B. Ricco [a], G.J. de Borst [a], S. Debus [a], J. de Haro [a], A. Halliday [a], G. Hamilton [a], J. Kakisis [a], S. Kakkos [a], S. Lepidi [a], H.S. Markus [a], D.J. McCabe [a], J. Roy [a], H. Sillesen [a], J.C. van den Berg [a], F. Vermassen [a], ESVS Guidelines Committee [b], P. Kolh, N. Chakfe, R.J. Hinchliffe, I. Koncar, J.S. Lindholt, M. Vega de Ceniga, F. Verzini, ESVS Guideline Reviewer erg, M. Venermo

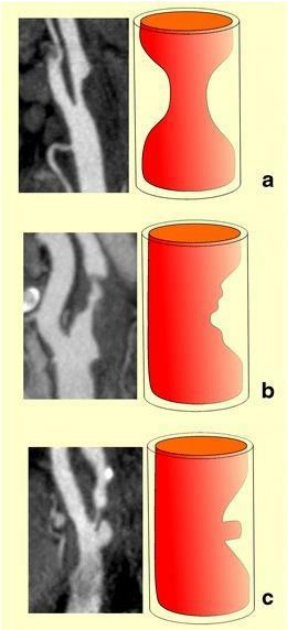
Keywords: Carotid Screeni technic Medical therapy, , Surgical

Plaque lucency on Duplex US[91] 50–99% stenoses Meta-analysis	Predominantly echolucent 4.2% Predominantly echogenic 1.6%	OR 2.61 (95% CI 1.47–4.63) $p = .001$
Spontaneous embolisation on TCD[92] 50–99% stenoses Meta-analysis	Yes vs. no	OR 7.46 (95% CI 2.24–24.89) $p = .001$
Spontaneous embolisation plus uniformly or predominantly echolucent plaque[93] 70–99% stenoses Multicentre, observational	Yes = 8.9% No = 0.8%	OR 10.61 (95% CI 2.98–37.82) $p = .0003$

Plaque surface

- Smooth
- Irregular
- Ulcerated





Insights Imaging. 2017 Apr; 8(2): 213–225.

Conclusions

Cervical arteries ultrasound:

- Is cervical artery healthy or not?
- What is the risk for stroke?
- Choice and the effect of medical treatment