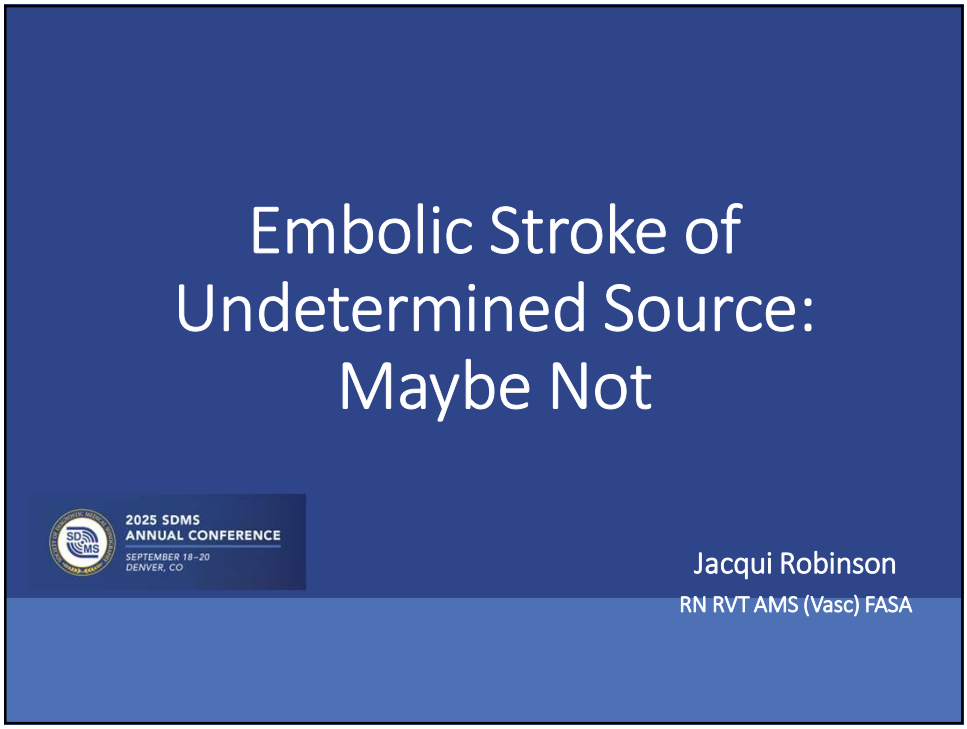

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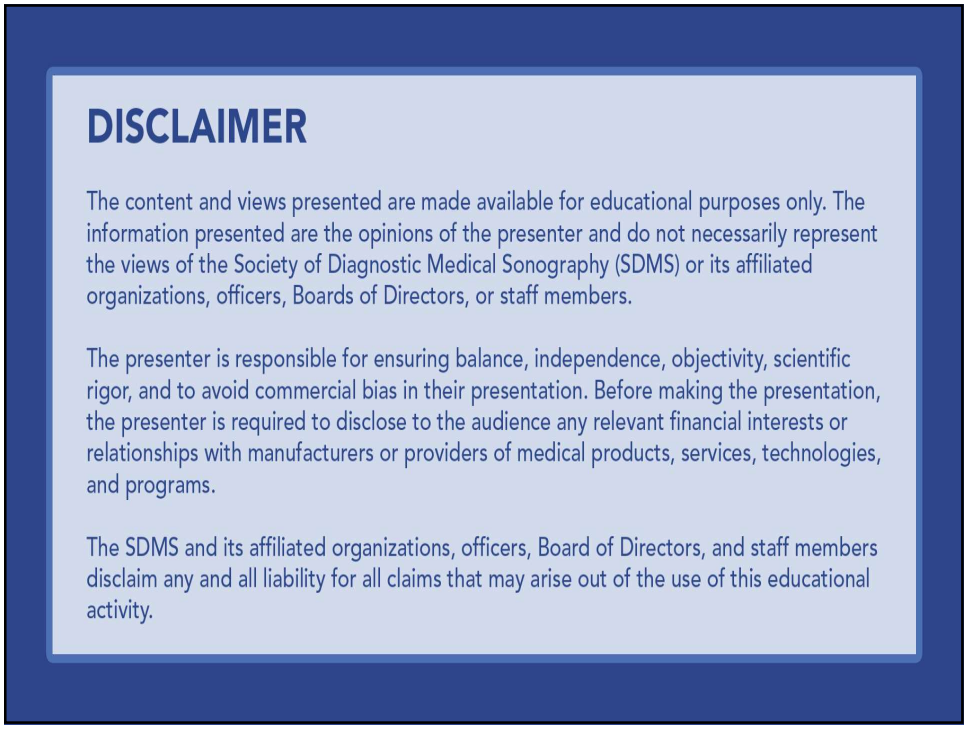

2

Educational objectives

- Explain the pathophysiology and risk factors associated with embolic stroke.
- Describe the use of duplex ultrasound to evaluate carotid artery abnormalities, plaque morphology, and flow dynamics.
- Recognize the sonographer's role as a key member of the multidisciplinary stroke care team.

Disclosure: I have no actual or potential conflict of interest in relation to this presentation

3

Presentation Outline

- Embolism
- Embolic Stroke of Undetermined Source (ESUS)
- Case based
- Extracranial carotid arteries

(1)

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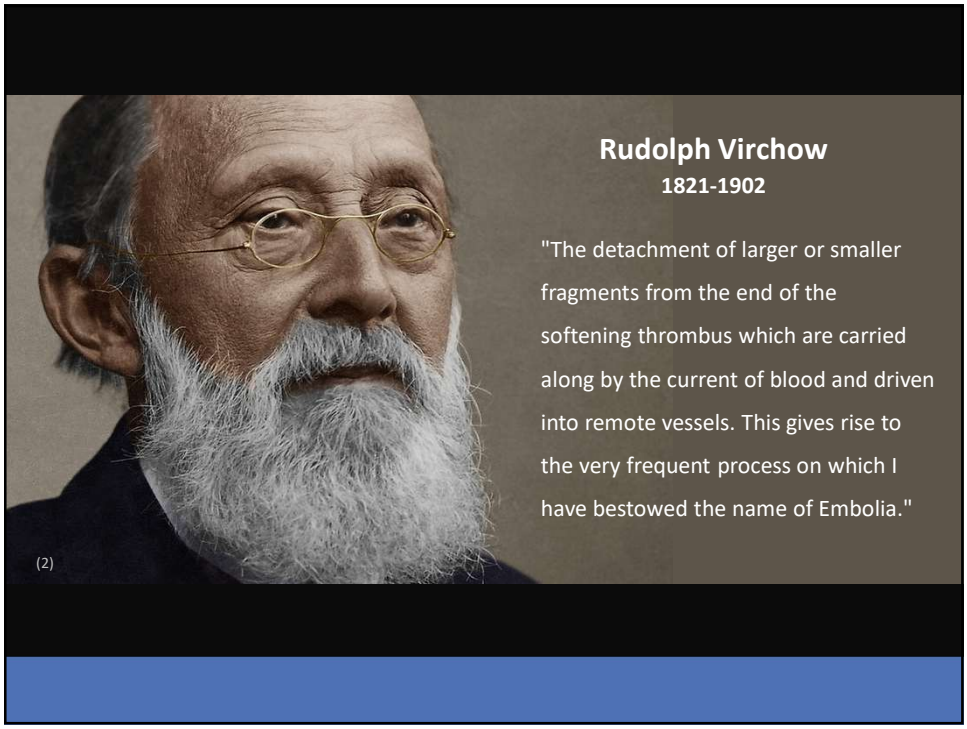

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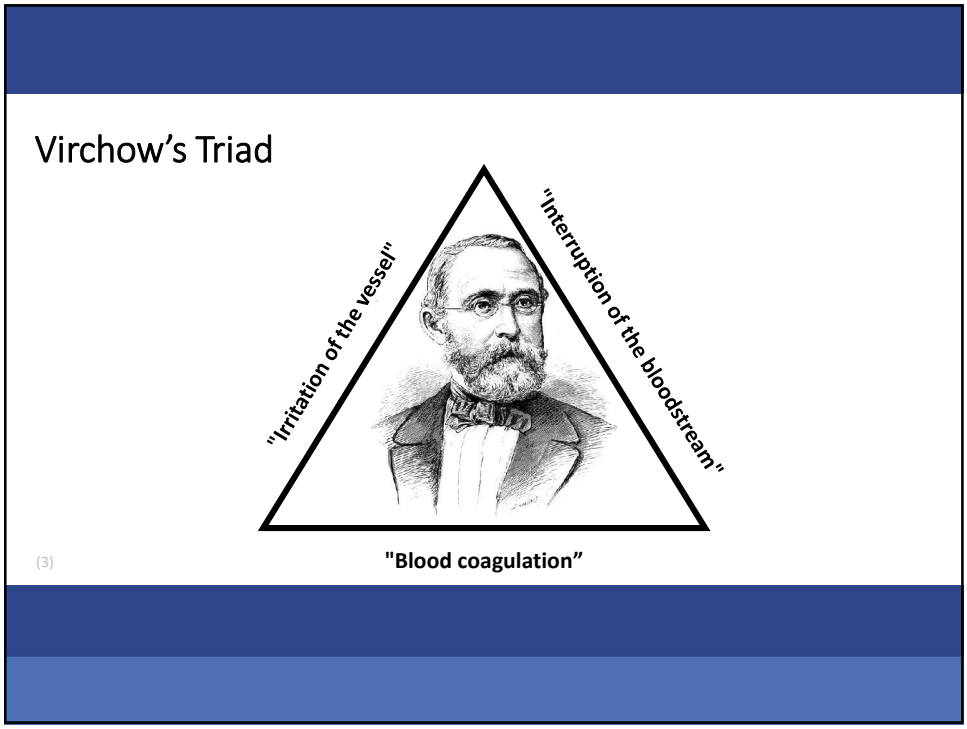

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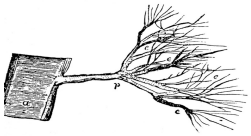
Virchow – Systemic Circulation Emboli

- Different to pulmonary emboli
  - Smaller
  - Arterioles
  - Abnormal -> normal
- Bacterial endocarditis
- Spleen, myocardium, kidney and brain
- Cause of stroke



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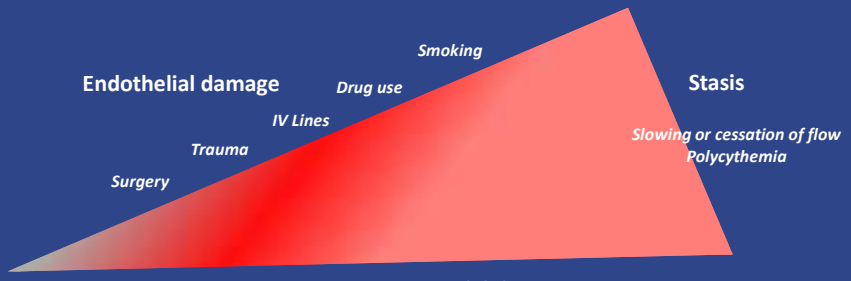
Virchow's Triad - contemporary concept



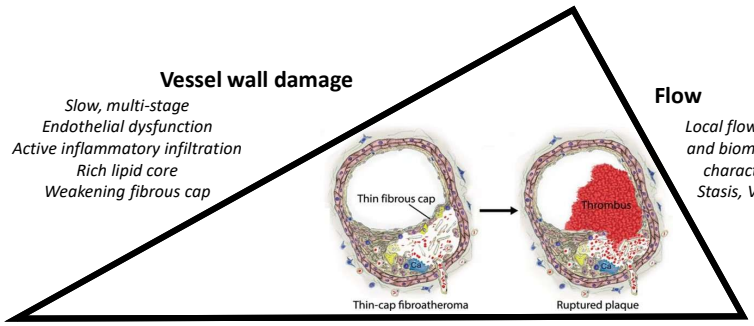
Hypercoagulability

Inherited
Factor V Leiden, Hyperhomocysteinemia
Protein C resistance, Protein S decrease

Acquired
Malignancy, Lupus, Renal failure, Diabetes
Thrombocytopenia, Immobility, Pregnancy,
OCP, HRT, Obesity, Smoking

8

Athero-embolism - applying Virchow's Triad



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9

Stroke

- 10% of deaths[6]
- 5% of global loss of disability-adjusted life years
- 200 per 100,000 population
- 80% of strokes are ischemic
  - ~25% cardioembolic

10

Embolic Stroke of Undetermined Source (ESUS)

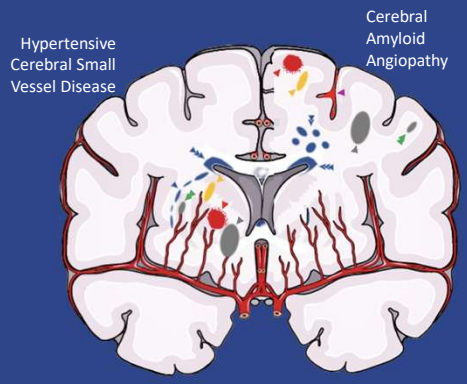
Non-lacunar ischemic stroke with no convincing etiology[7]

11

Embolic Stroke of Undetermined Source (ESUS)

Lacunar stroke

- Small-vessel disease
- Deep in brain
- Small infarcts
- Lacuna (hole) – small residual cavity after tissue death



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12

Embolic Stroke of Undetermined Source (ESUS)

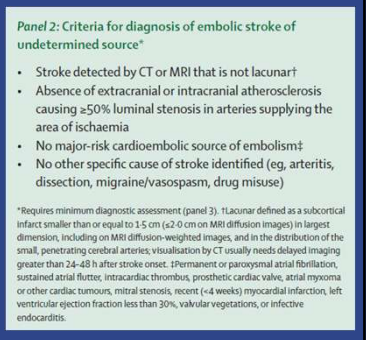
- 17% of all ischemic strokes[6]
- Younger patients
- Mild stroke
- Recurrent stroke risk 4-5% per-yr[9]
- Secondary prevention challenge

13

ESUS diagnosis

Exclude :

- Lacunar stroke
- Ipsilateral carotid artery disease ≥50%
- Major cardioembolic source
  - Atrial fibrillation
  - Sustained Atrial flutter
  - Intracardiac thrombus
  - Prosthetic valve / valve vegetations / infective endocarditis
  - Atrial myxoma / other tumours
  - Mitral stenosis
  - Recent myocardial infarct
  - LV Ejection fraction of ≤30%
- Dissection, arteritis, migraine, vasospasm, drug abuse



Panel 2: Criteria for diagnosis of embolic stroke of undetermined source*

- Stroke detected by CT or MRI that is not lacunar†
- Absence of extracranial or intracranial atherosclerosis causing ≥50% luminal stenosis in arteries supplying the area of ischaemia
- No major-risk cardioembolic source of embolism‡
- No other specific cause of stroke identified (eg, arteritis, dissection, migraine/vasospasm, drug misuse)

*Requires minimum diagnostic assessment (panel 3). †Lacunar defined as a subcortical infarct smaller than or equal to 1·5 cm (≤2·0 cm on MRI diffusion images) in largest dimension, including on MRI diffusion-weighted images, and in the distribution of the small, penetrating cerebral arteries; visualisation by CT usually needs delayed imaging greater than 24–48 h after stroke onset. ‡Permanent or paroxysmal atrial fibrillation, sustained atrial flutter, intracardiac thrombus, prosthetic cardiac valve, atrial myxoma or other cardiac tumours, mitral stenosis, recent (<4 weeks) myocardial infarction, left ventricular ejection fraction less than 30%, valvular vegetations, or infective endocarditis.

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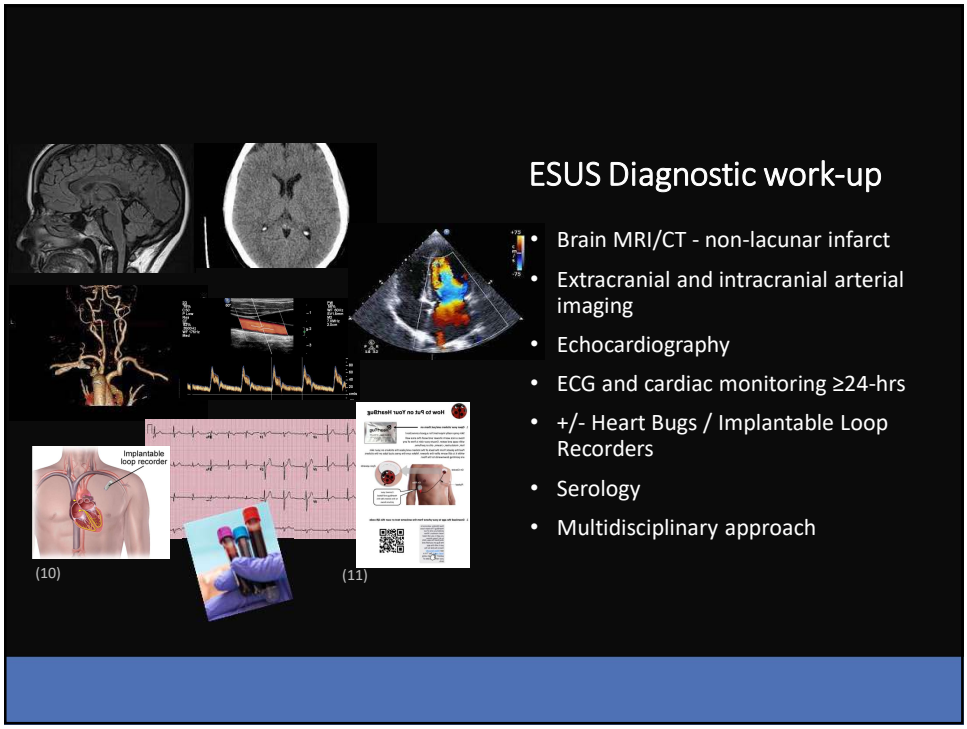

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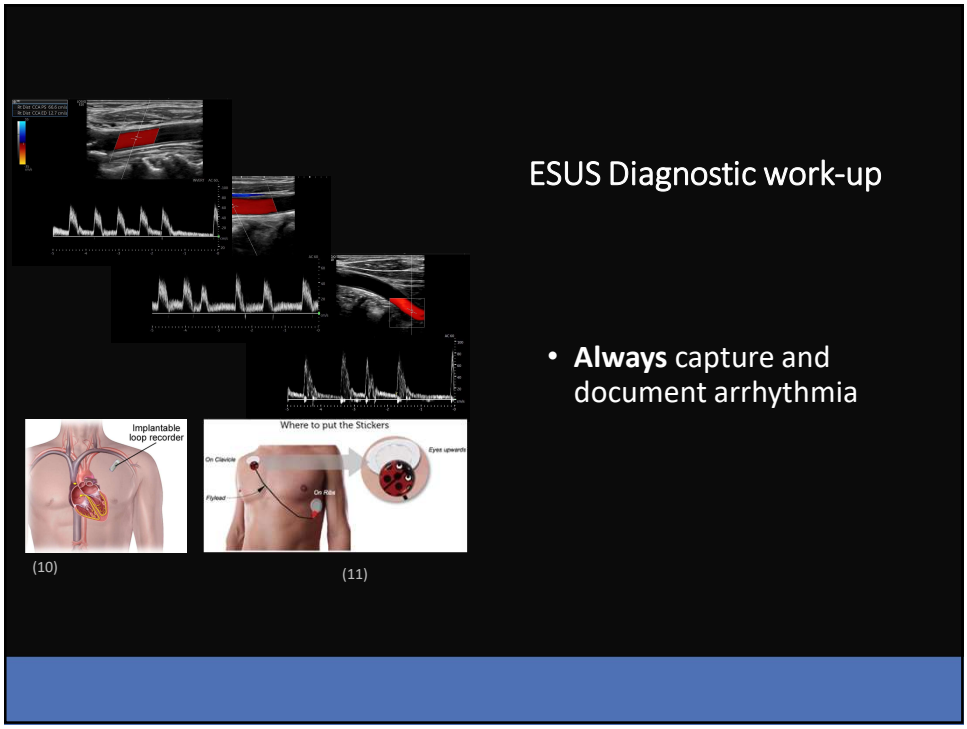

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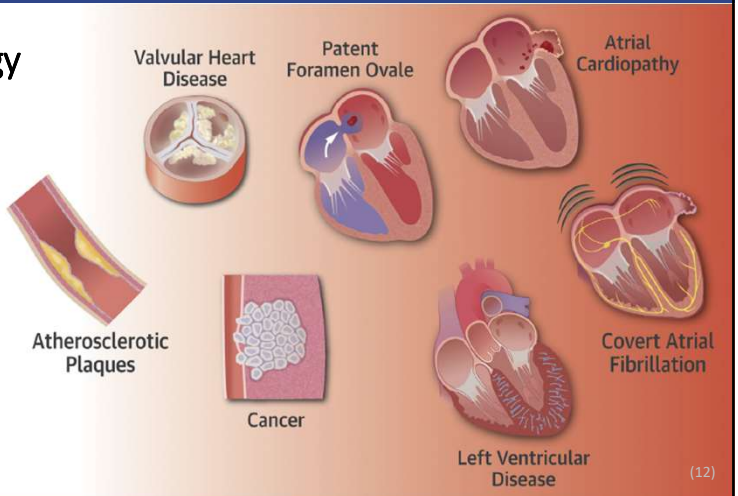
ESUS etiology



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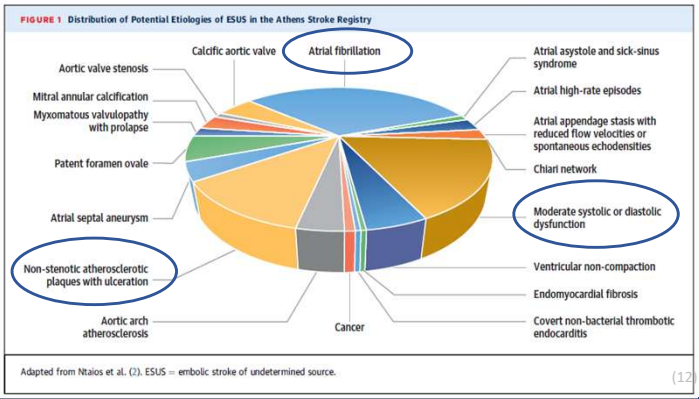
ESUS etiology



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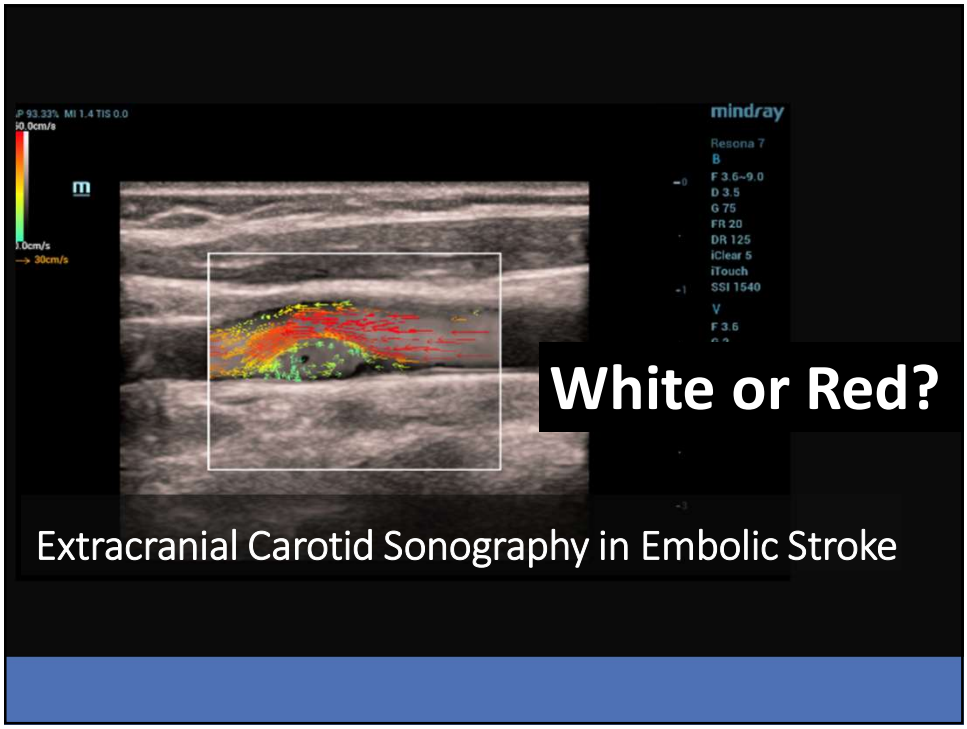

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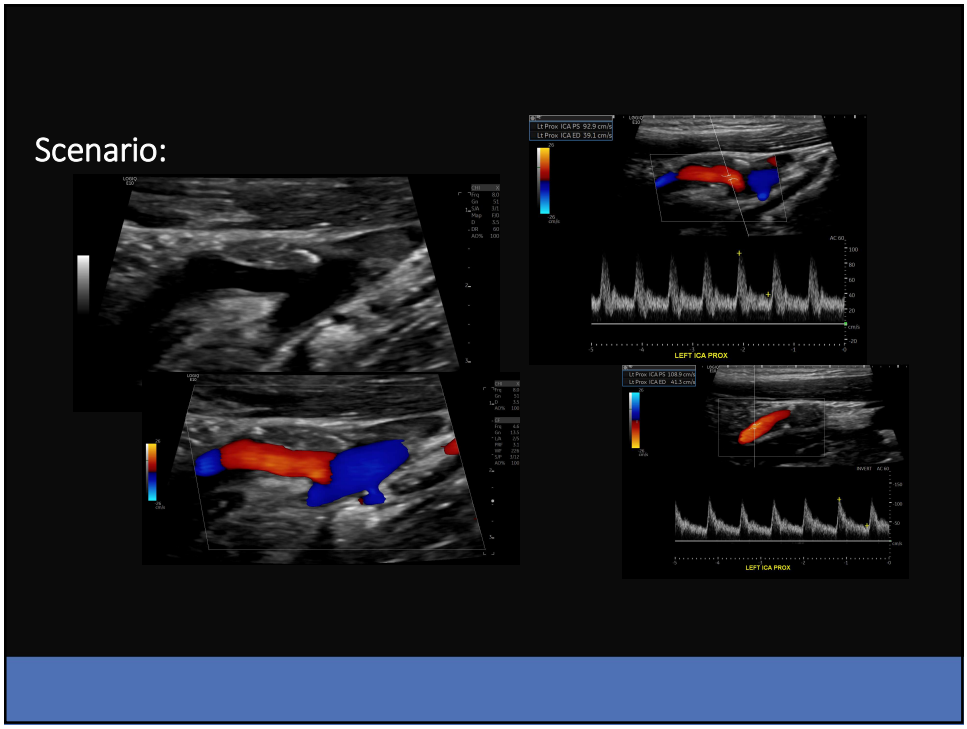

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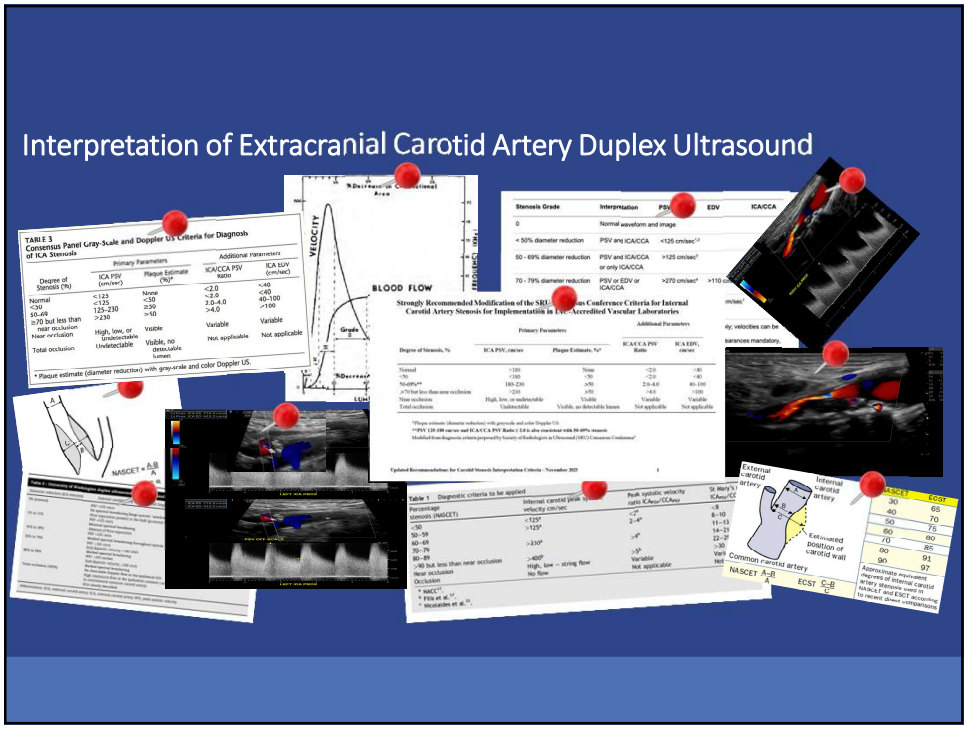

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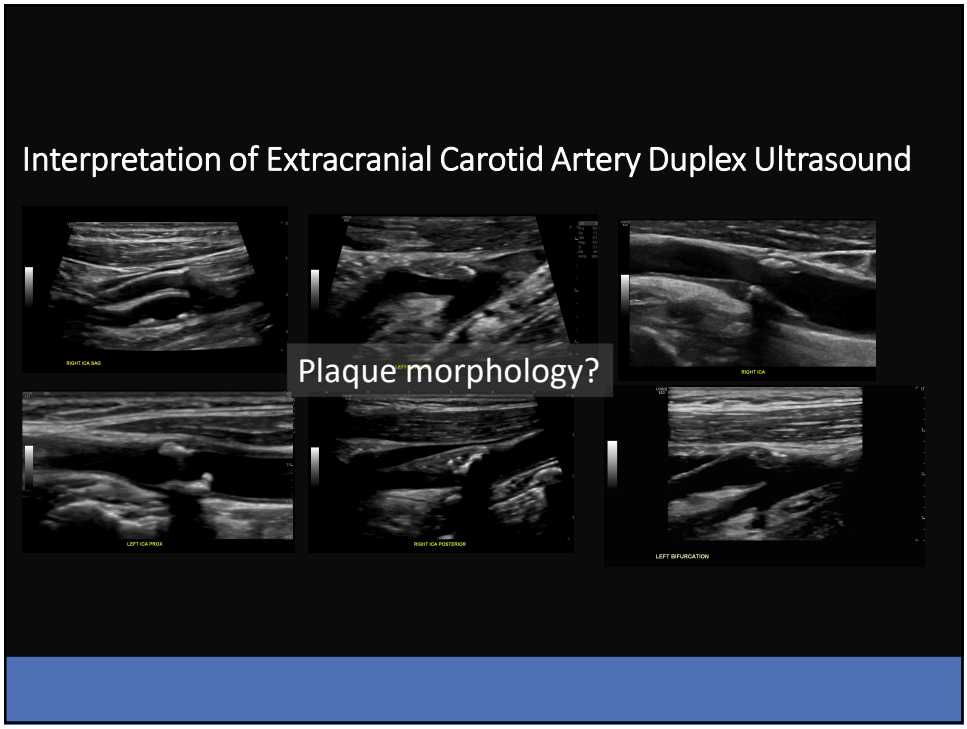

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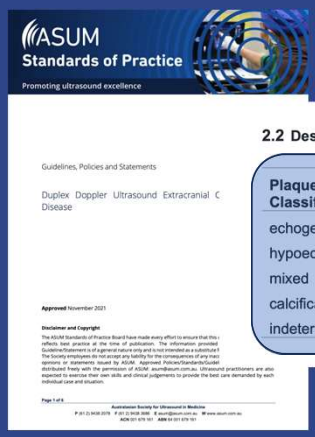
Extracranial Carotid Artery Duplex Ultrasound


ASUM
Standards of Practice
Promoting ultrasound excellence

Guidelines, Policies and Statements

Duplex Doppler Ultrasound Extracranial C
Disease

Approved November 2021

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2.2 Descriptions

Plaque Classification	Surface	Bifurcation	Tortuosity	Technical
echogenic	smooth	normal	minimal	poor
hypoechoic	irregular	high	moderate	good
mixed	indeterminate	low	maximum	excellent
calcification				
indeterminate				

(15)

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Extracranial Carotid Artery Duplex Ultrasound


SVU
SOCIETY FOR VASCULAR ULTRASOUND

VASCULAR TECHNOLOGY
PROFESSIONAL PERFORMANCE GUIDELINES

Extracranial Cerebrovascular
Duplex Ultrasound

B-mode imaging of the extracranial carotid arteries should be performed in longitudinal and transverse planes utilizing anterior, lateral and posterior-lateral probe positions. Optimize the gain to depict vessel walls, plaque and any other abnormalities.

- **B-mode images** should include the following:
  - Longitudinal image of the common carotid artery (CCA)
  - Transverse image of the carotid artery bifurcation
  - Longitudinal image of the internal carotid artery (ICA)
  - Longitudinal image of the external carotid artery (ECA)
    - The location, severity and characteristics of plaque should be documented in transverse and longitudinal planes.
    - Any other abnormalities should be documented.

(16)

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Extracranial Carotid Artery Duplex Ultrasound

Carotid Artery Stenosis: Gray-Scale and Doppler US Diagnosis—Society of Radiologists in Ultrasound Consensus Conference[1]

Recommendation.—The ICA US examination should consist of gray-scale imaging, color Doppler imaging, and spectral Doppler velocity determination. Because stenosis is typically an area of narrowing caused by plaque, with a focal area of increased velocity and a poststenotic disturbed flow, the location and characteristics of plaque in the ICA should be determined. The color Doppler appearance of the lumen should also be assessed.

(17)

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Extracranial Carotid Artery Duplex Ultrasound

THE SOCIETY FOR VASCULAR TECHNOLOGY OF GREAT BRITAIN AND IRELAND

Vascular Technology Professional Performance Guidelines

Extracranial Cerebrovascular Duplex Ultrasound Examination

Introduction

This guideline was prepared by the Professional Standards Committee (PSC) of the Society for Vascular Technology (SVT) as a template to aid the clinical vascular scientist / vascular sonographers and other interested parties. It can be used in conjunction with local protocols agreed between sonography, and / or vascular departments. It may be used in part or in its entirety with suitable additions made by local policy implementors, and should be read in combination with the following SVT guidelines when setting up a carotid artery scanning service:

- Vascular Ultrasound Service Specifications [1]

In addition, the SVU publication [2] provides detailed indications for carotid artery Duplex investigations.

Suggestions for improving this guideline are welcome, and should be sent to the Chair of the PSC; see www.svtgbi.org.uk for current Chair details.

Purpose

Extracranial cerebrovascular Duplex ultrasound examinations are carried out to assess for the presence of pathology and the haemodynamic status of the common carotid artery (CCA), internal carotid artery (ICA) external carotid artery (ECA) and vertebral artery.

Common Indications

Common indications for performing this examination include:

- Transient ischemic attacks (TIA)
- Amaurosis fugax
- Carotid bruit
- Cerebrovascular Accident (CVA)
- Follow-up of known carotid stenosis
- Post intervention follow-up e.g. carotid endarterectomy, stent or bypass
- Trauma in the distribution of the carotid artery e.g. suspected dissection, arteriovenous fistula or pseudoaneurysm
- Pre-operative assessment for high risk patients e.g. coronary artery bypass surgery (CABG)
- Pulsatile neck masses
- Evaluation of suspected subclavian steal syndrome

- Qualitatively note the nature of the plaque e.g. calcified, echolucent, irregular, smooth etc. the length and anatomical position

(18)

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Extracranial Carotid Artery Duplex Ultrasound

REVIEW

Joint Recommendations for Reporting Carotid Ultrasound Investigations in the United Kingdom

C.P. Oates[a,*], A.R. Naylor[b], T. Hartshorne[b], S.M. Charles[c], T. Fail[d], K. Humphries[e], M. Aslam[f], P. Khodabakhsh[g]

- In the case of a large plaque in a large bulb (>10 mm dia) measure and report the bulb diameter, plaque thickness and residual lumen
- Qualitatively note the nature of the plaque (calcified, irregular, echo-poor, etc.)
- Record length of longer stenoses

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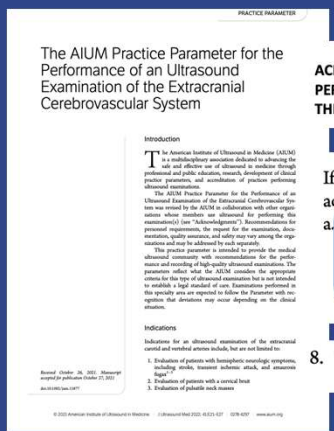
Extracranial Carotid Artery Duplex Ultrasound



PRACTICE PARAMETER

The AIUM Practice Parameter for the Performance of an Ultrasound Examination of the Extracranial Cerebrovascular System

ACR–AIUM–SPR–SRU PRACTICE PARAMETER FOR THE PERFORMANCE OF AN ULTRASOUND EXAMINATION OF THE EXTRACRANIAL CEREBROVASCULAR SYSTEM

If abnormalities are found, additional images must be acquired:

a. If atherosclerotic plaque is present, location, extent, and characteristics should be documented with grayscale imaging in both longitudinal and transverse planes.

8. The report may characterize plaques, depending on the laboratory interpretation criteria.[20–24]

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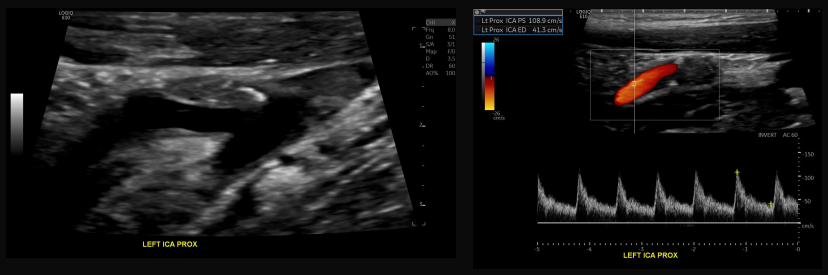
Duplex Ultrasound – complex sub-stenotic atherosclerotic disease - 1



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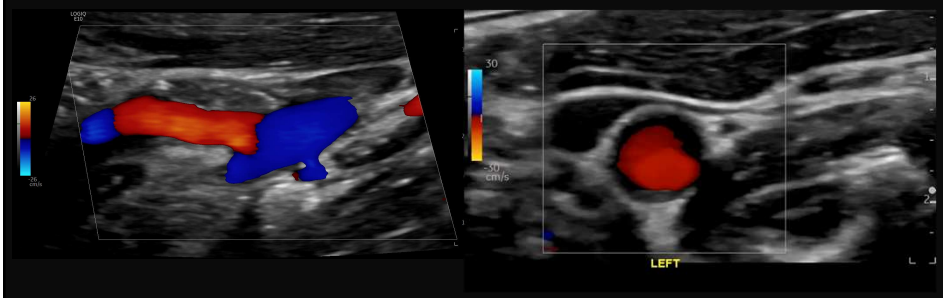
Duplex Ultrasound – complex sub-stenotic atherosclerotic disease - 1



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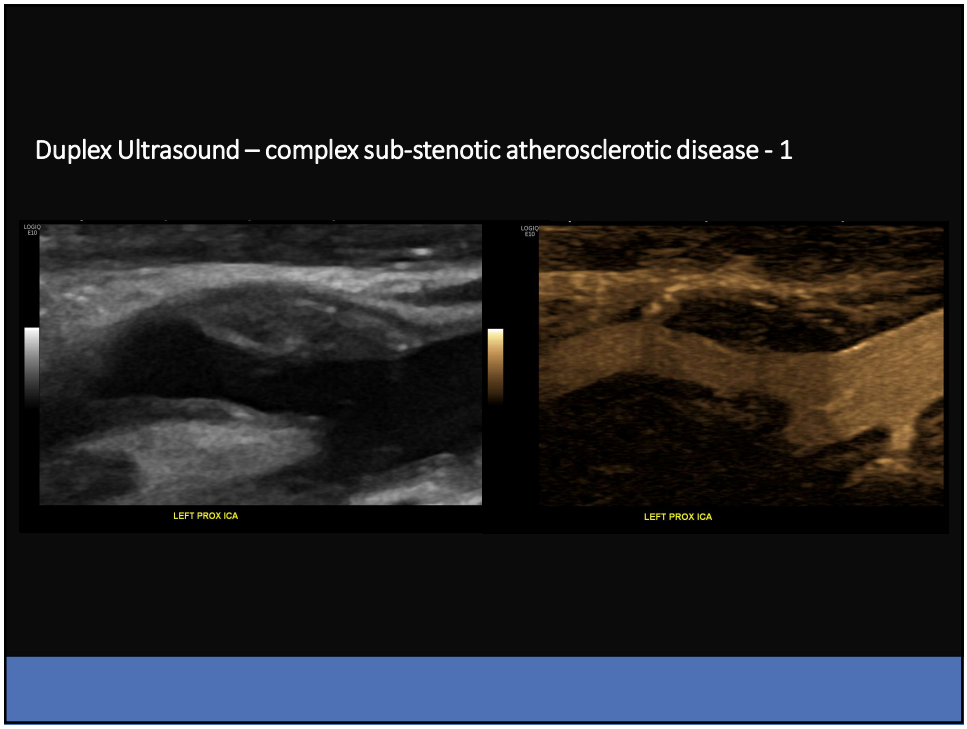

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Duplex Ultrasound – complex sub-stenotic atherosclerotic disease - 1

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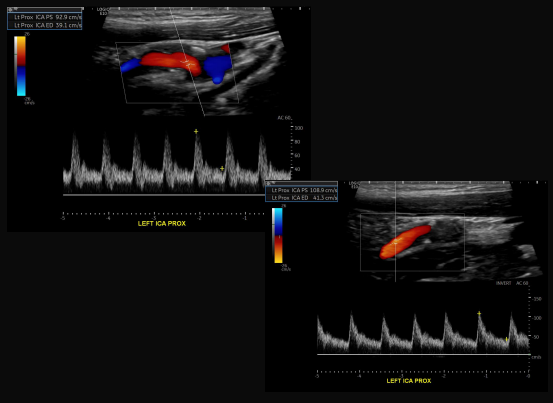
Duplex Ultrasound – complex sub-stenotic atherosclerotic disease - 1

	Left	
	PS	ED
Prox CCA	62.6cm/s	17.0cm/s
Mid CCA	83.1cm/s	25.9cm/s
Dist CCA	95.1cm/s	34.7cm/s
Prox ICA	108.9cm/s	41.3cm/s
Mid ICA	80.9cm/s	35.8cm/s
Dist ICA	68.8cm/s	29.2cm/s
Prox ECA	88.5cm/s	21.5cm/s
Mid VERT	68.8cm/s	27.0cm/s
ICA/CCA	1.3	1.6



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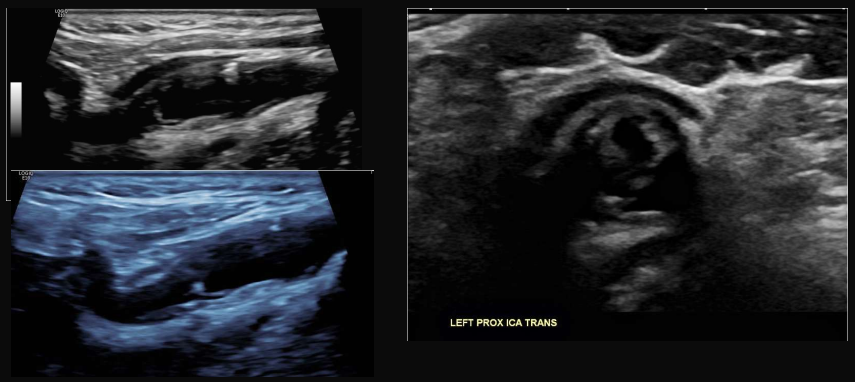
Duplex Ultrasound – complex sub-stenotic atherosclerotic disease - 2



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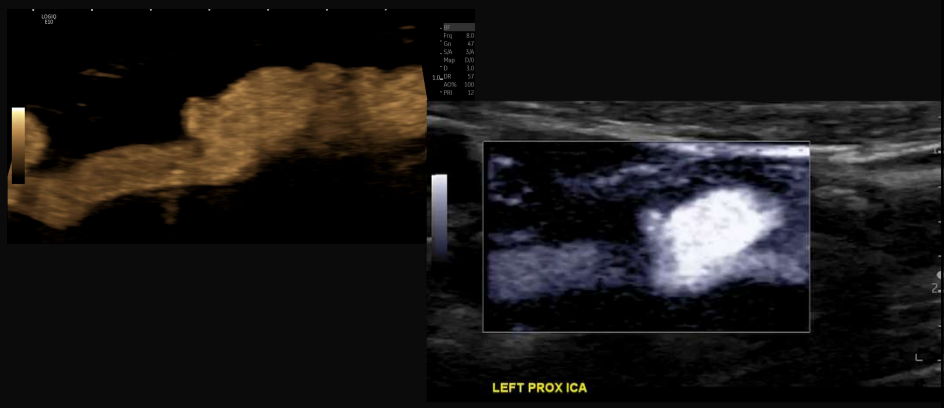
Duplex Ultrasound – complex sub-stenotic atherosclerotic disease - 2



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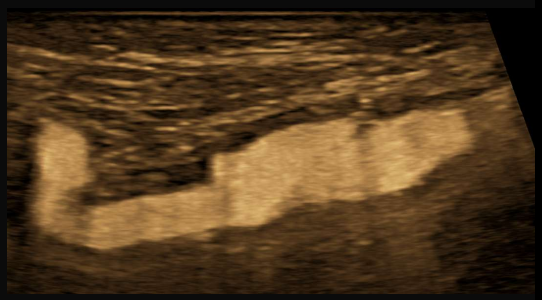
Duplex Ultrasound – complex sub-stenotic atherosclerotic disease - 2



	Left	
	PS	ED
Mid CCA	114.3cm/s	19.4cm/s
Dist CCA	94.1cm/s	20.4cm/s
Prox ICA	83.4cm/s	27.4cm/s
Mid ICA	94.0cm/s	25.4cm/s
Dist ICA	72.7cm/s	20.6cm/s
Prox ECA	96.5cm/s	11.8cm/s
Mid VERT	59.1cm/s	16.6cm/s
ICA/CCA	0.9	1.3

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Carotid Endarterectomy

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Carotid Endarterectomy

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The Vulnerable Plaque

Symposia

The Efficacy of Emerging Ultrasound Applications in Characterizing Vulnerable Carotid Plaques

Journal of Diagnostic Medical Sonography
2025, Vol. 41(5) 510-516

DOI: 10.1177/87564793241311545
journals.sagepub.com/home/jdm
Sage

Jim Baun, MEd, RDMS, RVT, FSDMS[1]

Abstract
The emergence and integration of nonconventional ultrasound applications into the vascular diagnostic armamentarium offers the opportunity for answering a long-standing question about the morphological makeup of focal carotid atherosclerotic lesions, that is, is this particular plaque vulnerable or not? Vulnerable lesions are those which, based on their histological and morphological features, predispose a patient to an increased risk of a cerebral ischemic event (CIE) secondary to plaque or thrombus embolization. The ability to reliably differentiate plaque types using readily available noninvasive imaging methods facilitates risk stratification in both symptomatic and asymptomatic patients. Improved identification of at-risk lesions makes more targeted patient management and/or interventional decisions possible. Three emerging ultrasound applications that have demonstrated efficacy in offering this enhanced diagnostic capability are point shear wave elastography (pSWE), contrast-enhanced ultrasound (CEUS), and microvascular ultrasound imaging (MUI).

Keywords
Carotid pathology, contrast-enhanced ultrasound, microvascular ultrasound imaging, and point shear wave elastography

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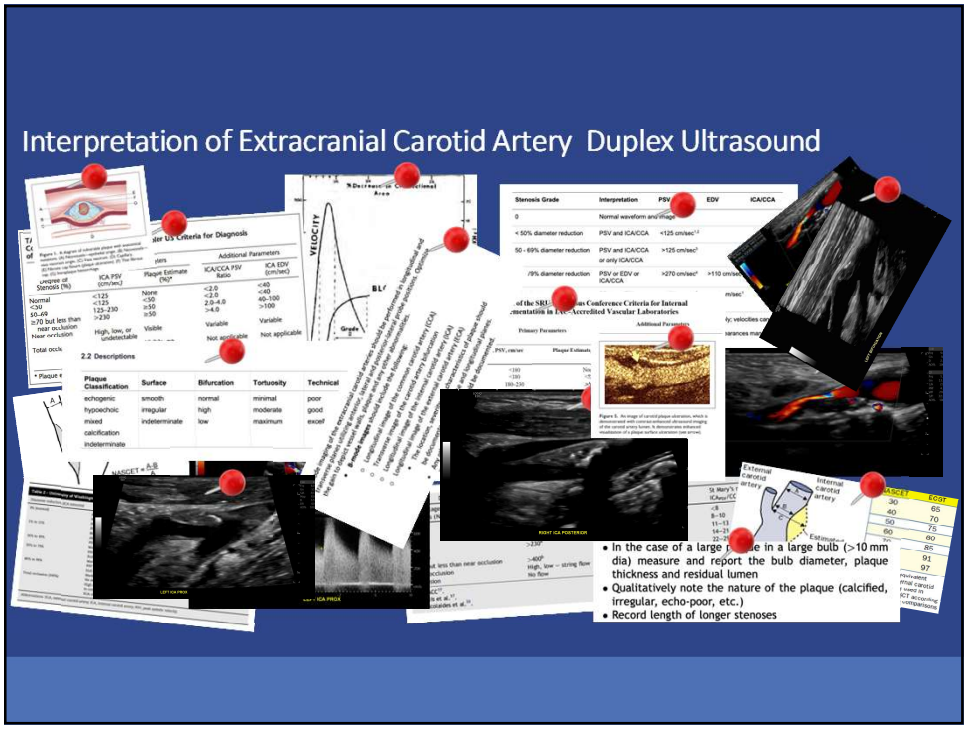

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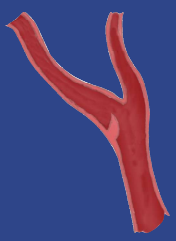
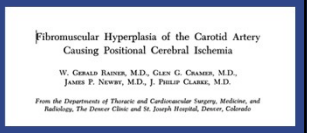
Carotid web

- Rainer - 1968[22]
- Variant intimal fibromuscular dysplasia
- Shelf-like projection into bulb
- Young stroke
- F>M





Fibromuscular Hyperplasia of the Carotid Artery Causing Positional Cerebral Ischemia

W. Gerald Rainer, M.D., Glen G. Cramer, M.D., James P. Newby, M.D., J. Philip Clarke, M.D.

From the Departments of Thoracic and Cardiovascular Surgery, Medicine, and Radiology, The Denver Clinic and St. Joseph Hospital, Denver, Colorado

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Carotid web etiology

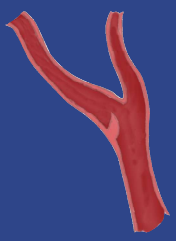
Unclear and controversial

Congenital

- Embryological remnant?
- Developmental anomaly?
- Genetic factors?
- Intimal fibrous proliferation - *without atherosclerosis*

Acquired

- *Case reports*

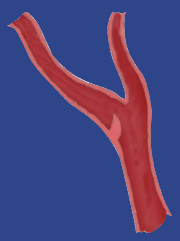


- Focal intimal dissection

44

- Embolic stroke of undetermined source (ESUS)
- Prevalence 9.6% [23]
- Ipsilateral
  - 24% <55yrs

Carotid web



- Female
- African heritage
- Further studies needed

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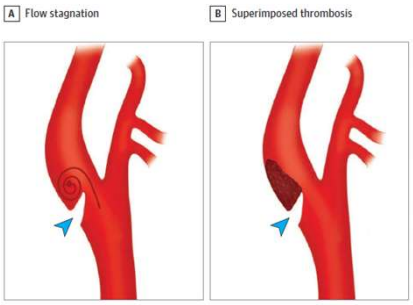
Carotid web

- Recirculation, flow stasis and thrombogenesis
- Medical treatment
  - Antiplatelet
- Interventional treatment
  - Carotid stent
  - Carotid web resection



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Carotid web

Recommendation 61 — New

For symptomatic patients with a carotid web in whom no other cause for stroke can be identified after detailed neurovascular work up, carotid endarterectomy or carotid artery stenting may be considered to prevent recurrent stroke.

Class	Level	References	ToE
IIb	C	Gugliemi *et al.* (2021)[19], Kim *et al.* (2019)[69], Zhang *et al.* (2013)[241], Choi *et al.* (2015)[426], Laberyie *et al.* (2021)[427]	

> Eur J Vasc Endovasc Surg. 2023 Jan;65(1):7-111. doi: 10.1016/j.ejvs.2022.04.011. Epub 2022 May 20. (25)

Editor's Choice – European Society for Vascular Surgery (ESVS) 2023 Clinical Practice Guidelines on the Management of Atherosclerotic Carotid and Vertebral Artery Disease

Recommendations for Carotid Web
Referenced studies that support recommendations are summarized in online Data Supplement 33.

COR	LOE	Recommendations
1	B-NR	1. In patients with carotid web in the distribution of ischemic stroke and TIA, without other attributable causes of stroke, antiplatelet therapy is recommended to prevent recurrent ischemic stroke or TIA.[748,749]
2b	C-LD	2. In patients with carotid web in the distribution of ischemic stroke refractory to medical management, with no other attributable cause of stroke despite comprehensive workup, carotid stenting or CEA may be considered to prevent recurrent ischemic stroke.[748–750]

Review > Stroke. 2021 Jul;52(7):e364-e467. doi: 10.1161/STR.0000000000000375. Epub 2021 May 24. (26)

2021 Guideline for the Prevention of Stroke in Patients With Stroke and Transient Ischemic Attack: A Guideline From the American Heart Association/American Stroke Association

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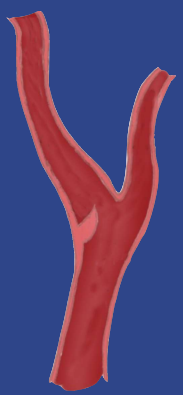
Carotid web – diagnosis

- Digital subtraction angiography (DSA)
- CT Angiography
- Magnetic Resonance Angiography
- Ultrasound
- Contrast enhanced ultrasound



48

Carotid web

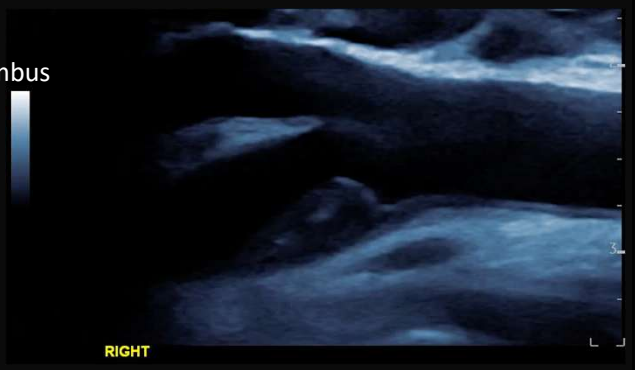
Imaging characteristics

- Motionless triangular lesion
- Protrudes into the lumen
- ICA wall
- Varies in size
- Iso / hypoechoic
- Longitudinal view
- Easily missed

49

Carotid web

- Flow stasis and thrombus formation



50

Carotid web

Imaging characteristics

Review > J Neurol Neurosurg Psychiatry. 2020 Dec;91(12):1283-1289.
doi: 10.1136/jnnp-2020-323938. Epub 2020 Oct 1.

Carotid web: an occult mechanism of embolic stroke

Brian Mac Grory [1], Bart J Emmer [2], Stefan D Roosendaal [2], David Zagzag [3], Shadi Yaghi [4], Erez Nossek [5]

Table 1 Imaging characteristics of carotid webs compared with common radiographic mimics

	Carotid web	Atherosclerosis	Arterial dissection	Intraluminal thrombus
Stenosis	Rarely	Can cause stenosis or occlusion	Can cause stenosis or occlusion	Can cause stenosis or occlusion
Location	Arising from posterior wall of proximal ICA	At sites of maximum turbulence	Proximal ICA, can propagate distally	Can arise anywhere in extracranial or intracranial circulation
Morphology	Shelf-life, regular. Can be irregular if there is superimposed thrombus.	Irregular	Irregular, can have a 'spiral' appearance	Irregular, can have free-floating components
Calcium	No	Frequently present	No	No
Temporality	Does not change with time (unless there is superimposed thrombus)	Can progress or regress	Resolves with time	Resolves with time
Other	Can be bilateral	Evidence of atherosclerosis elsewhere in cervical and intracranial circulation	Presence of true and false lumen	Likely to change in appearance in the order of hours to days

ICA, internal carotid artery.

(27)

51

Carotid web

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52

Carotid web

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53

Carotid web

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Carotid web

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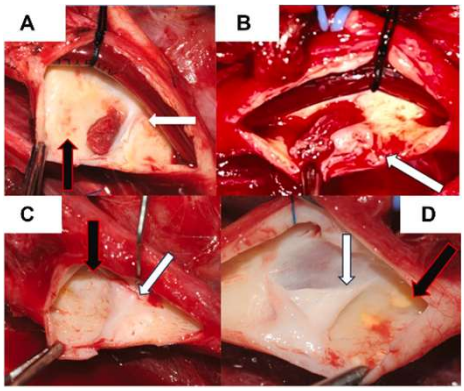
(27)

56

Carotid web



> J Vasc Surg. 2024 Jan;79(1):62-70. doi: 10.1016/j.jvs.2023.09.002. Epub 2023 Sep 7.

Symptomatic carotid webs require aggressive intervention

Clayton J Brinster [1], James O'Leary [2], Aaron Hayson [2], Andrew Steven [3], Charles Leithead [2], W Charles Sternbergh 3rd [2], Samuel R Money [2], Gabriel Vidal [4]

Affiliations + expand

PMID: 37683767 DOI: 10.1016/j.jvs.2023.09.002

(28)

Fig 3. Gross appearance of carotid webs (CaWebs) during operative exploration for carotid endarterectomy (CEA). **A and B,** CaWebs with associated, adherent thrombus (*white arrows*). **C,** "Prism" morphology CaWeb (*white arrow*). **D)** "Veil" morphology CaWeb (*white arrow*). *Black arrows* **(A, C and D)** show intimal changes noted distal to CaWeb, including discoloration, thickening, and, in image **(D)**, focal calcifications, demonstrating chronic inflammation consistent with turbulent blood flow resulting from CaWeb.

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Carotid web – case 1

- 36-yr-old male
- Right hemispheric embolic stroke

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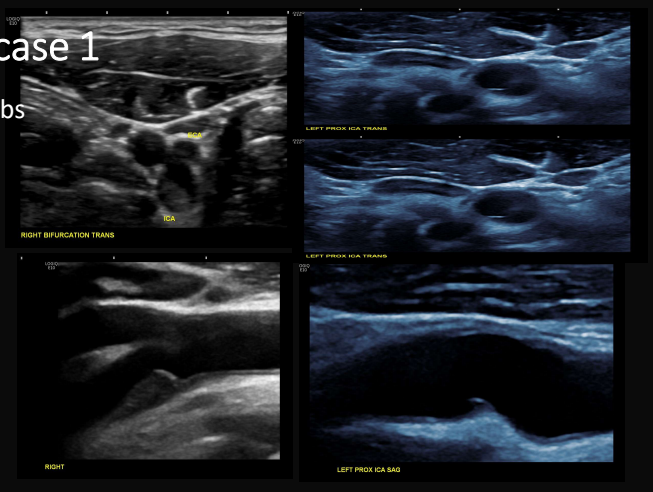
Carotid web – case 1

- Right hemispheric embolic stroke

59

Carotid web – case 1

- Bilateral carotid webs



60

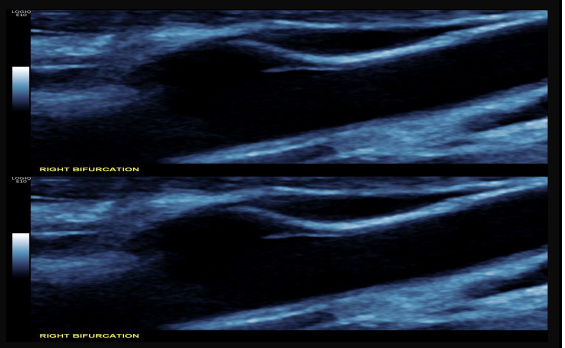
Carotid web – case 1

- Bilateral carotid webs

61

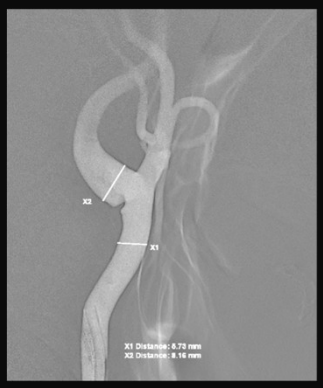
Carotid web – case 2

- 64-yr-old male
- Right hemispheric embolic stroke
- Bilateral webs on DUS



62

Carotid web – case 2



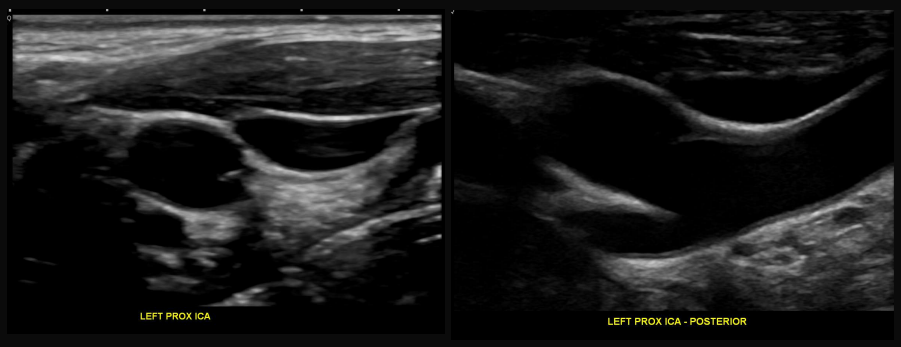
63

Carotid web – case 3

- 57-yr-old female
- Seizures
- PH of traumatic brain injury
- CTA – small left ICA intimal flap, suggesting dissection
- Duplex to characterize

64

Carotid web – case 3



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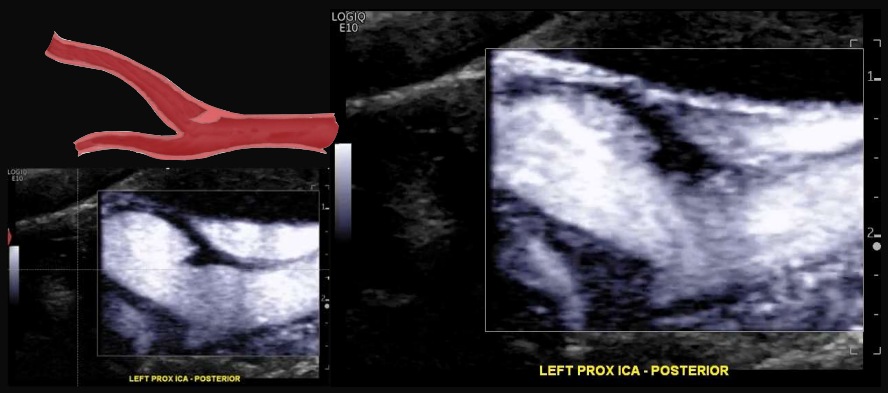
Carotid web – case 3



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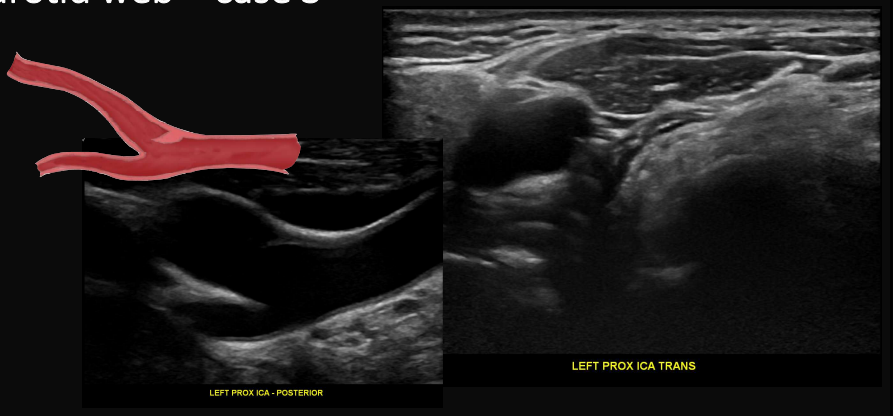
Carotid web – case 3



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Carotid web – case 3

Neuroimaging MDT meeting

https://tvtropes.org/pmwiki/pmwiki.php/ComicStrip/Garfield

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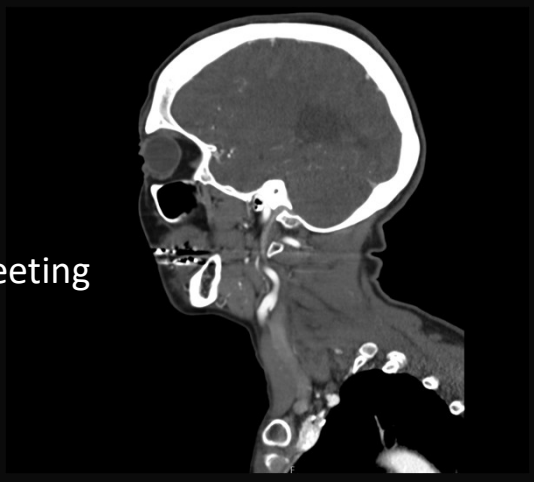
Carotid web – case 3

Neuroimaging MDT meeting



69

Carotid web – case 4

- 38-yr-old female
- Young stroke work-up
- Right hemispheric embolic stroke
- CTA – 50% stenosis at C5 level CCA
- RFs: Smoker, hypercholesterolemia, newly diagnosed T2M

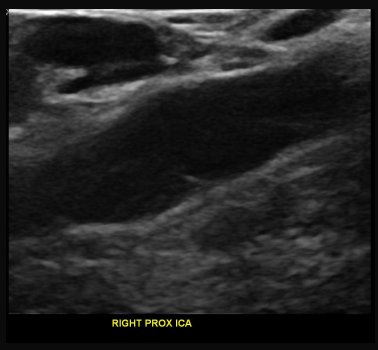
70

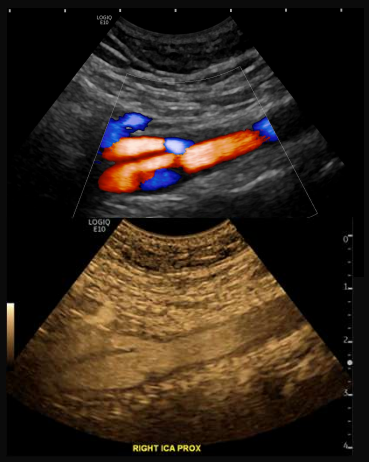
Carotid web – case 4

- Complex, mobile lesion RIGHT CCA
- ∽ 3.0cms length
- No velocity or ratio increase

71

Carotid web – case 4





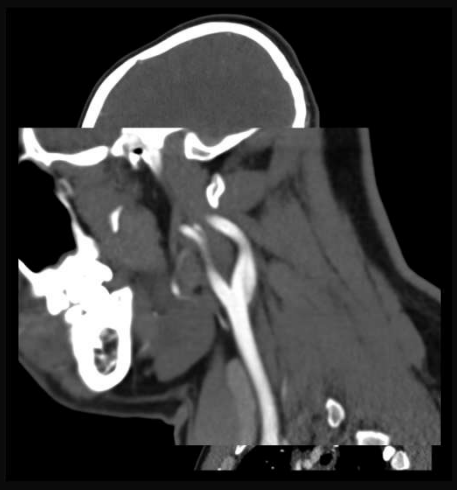
72

Carotid web – case 4

73

Carotid web – case 5

- 35-yr-old male
- Left amaurosis fugax
- CT brain normal
- CTA - bilateral carotid webs



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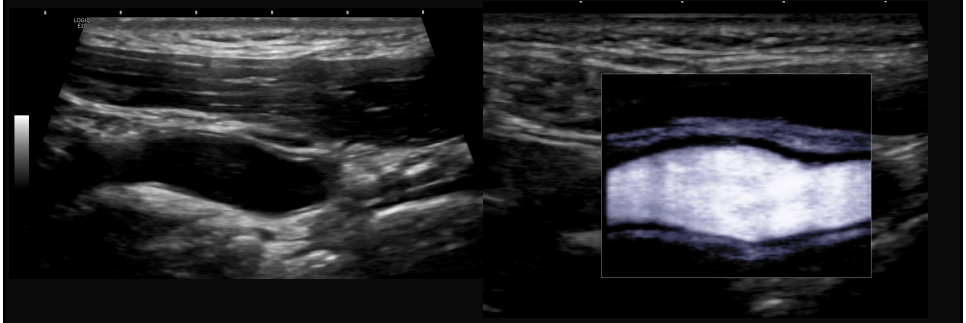
Case 5 -Duplex ultrasound study



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Case 5 -Duplex ultrasound study

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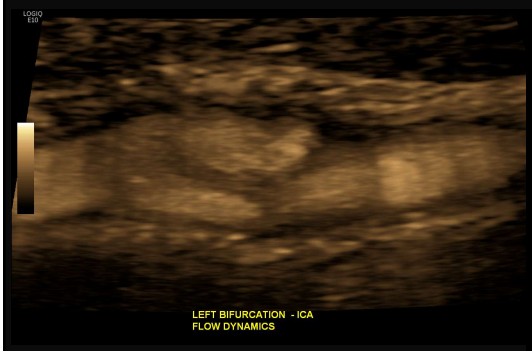
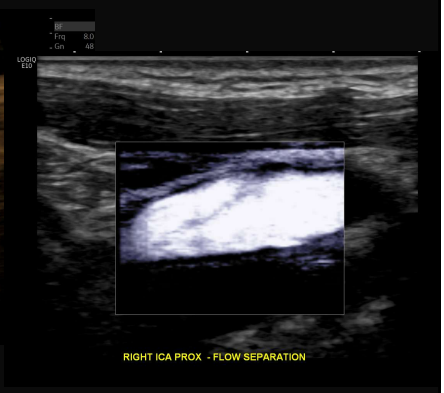
Case 5 -Duplex ultrasound study





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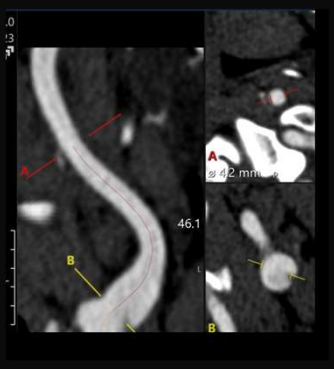
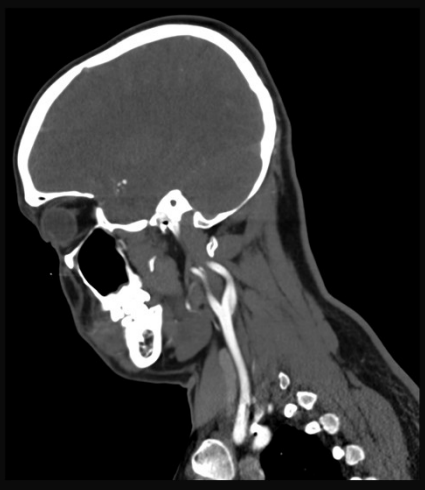
CT Angiography





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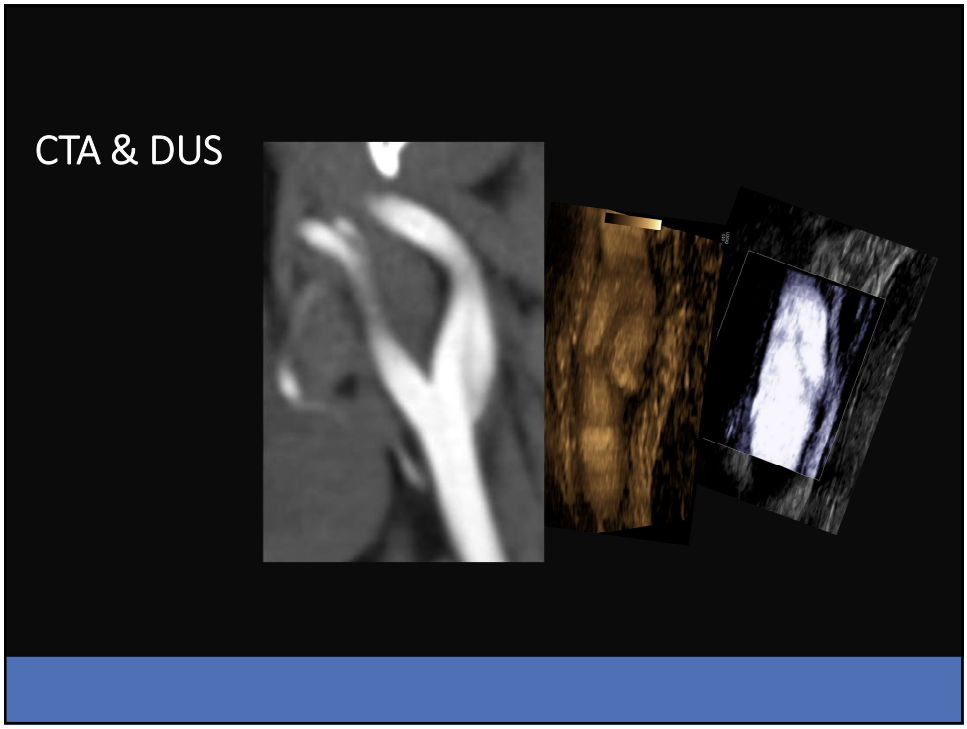

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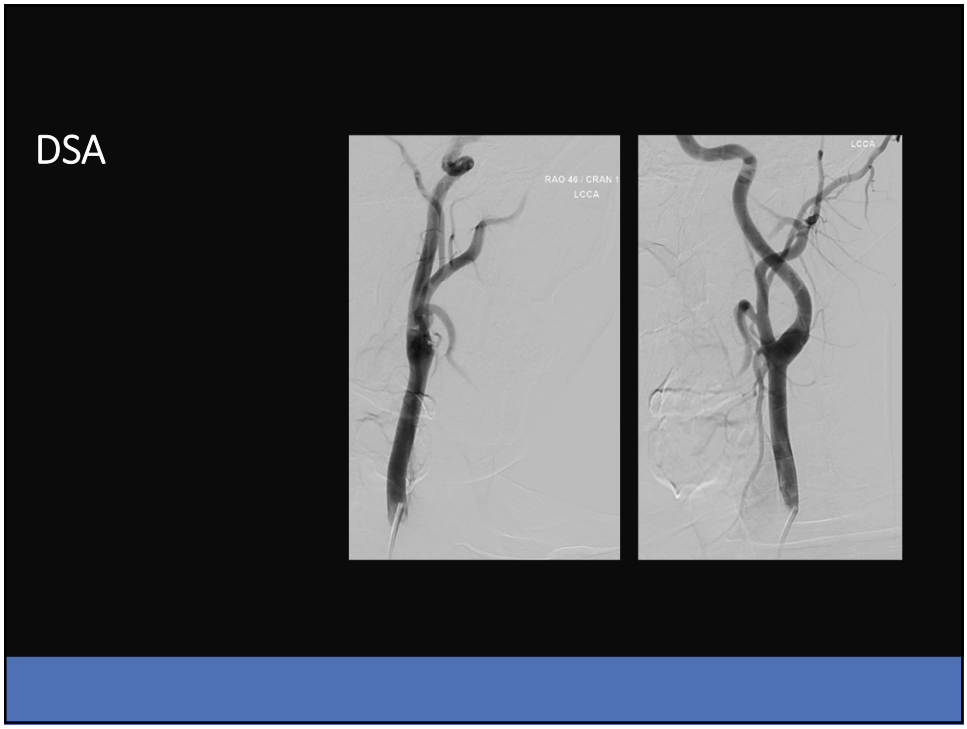

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Carotid web

- Future directions

World Neurosurg. 2024 Feb;182:e245-e252. doi: 10.1016/j.wneu.2023.11.091. Epub 2023 Nov 24.

Use of Carotid Web Angioarchitecture for Stroke Risk Assessment

Grace G von Oste [1], Karl L Sangwon [2], Charlotte Chung [1], Vinayak Narayan [3], Eytan Raz [3], Maksim Shapiro [3], Caleb Rutledge [3], Peter Kim Nelson [3], Koto Ishida [3], Jose L Sorias [4], Sara K Rostanski [4], Cen Zhang [4], Shadi Yaghi [3], Howard Riina [3], Eric K Oermann [3], Erez Nossek [3]

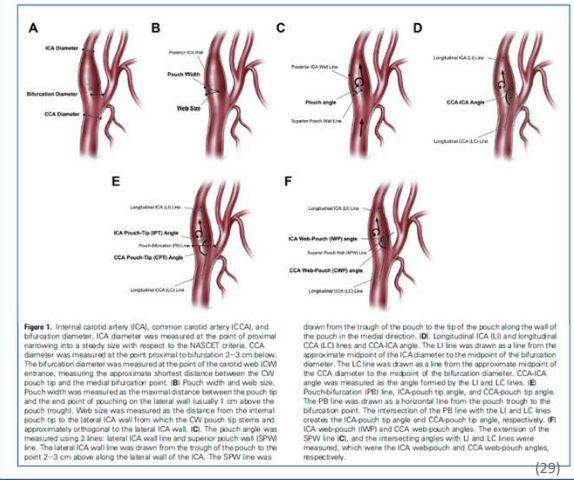

Figure 1. Internal carotid artery (ICA), common carotid artery (CCA), and bifurcation diameter. ICA diameter was measured at the point of proximal narrowing into a steady size with respect to the NASCET criteria. CCA diameter was measured at the point proximal to bifurcation 2–3 cm below. The bifurcation diameter was measured at the point of the carotid web (CW) entrance, measuring the approximate shortest distance between the CW pouch tip and the medial bifurcation point. (**B**) Pouch width and web size. Pouch width was measured as the maximal distance between the pouch tip and the end point of pouching on the lateral wall (usually 1 cm above the pouch trough). Web size was measured as the distance from the internal pouch tip to the lateral ICA wall from which the CW pouch tip stems and approximately orthogonal to the lateral ICA wall. (**C**) The pouch angle was measured using 2 lines: lateral ICA wall line and superior pouch wall (SPW) line. The lateral ICA wall line was drawn from the trough of the pouch to the point 2–3 cm above along the lateral wall of the ICA. The SPW line was drawn from the trough of the pouch to the tip of the pouch along the wall of the pouch in the medial direction. (**D**) Longitudinal ICA (LI) and longitudinal CCA (LC) lines and CCA-ICA angle. The LI line was drawn as a line from the approximate midpoint of the ICA diameter to the midpoint of the bifurcation diameter. The LC line was drawn as a line from the approximate midpoint of the CCA diameter to the midpoint of the bifurcation diameter. CCA-ICA angle was measured as the angle formed by the LI and LC lines. (**E**) Pouch-bifurcation (PB) line, ICA-pouch tip angle, and CCA-pouch tip angle. The PB line was drawn as a horizontal line from the pouch trough to the bifurcation point. The intersection of the PB line with the LI and LC lines creates the ICA-pouch tip angle and CCA-pouch tip angle, respectively. (**F**) ICA web-pouch (IWP) and CCA web-pouch angles. The extension of the SPW line (**C**), and the intersecting angles with LI and LC lines were measured, which were the ICA webpouch and CCA web-pouch angles, respectively.

(29)

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Carotid web

- Future directions

J Magn Reson Imaging. 2024 Jun;59(6):2001-2010. doi: 10.1002/jmri.29013. Epub 2023 Sep 14.

Assessment of Complex Flow Patterns in Patients With Carotid Webs, Patients With Carotid Atherosclerosis, and Healthy Subjects Using 4D Flow MRI

Retta El Sayed [1, 2], Charlie C Park [2], Zahraw Shah [1], Fadi B Nahab [3], Diogo C Haussen [3], Jason W Allen [1, 2, 3], John N Oshinski [1, 2]

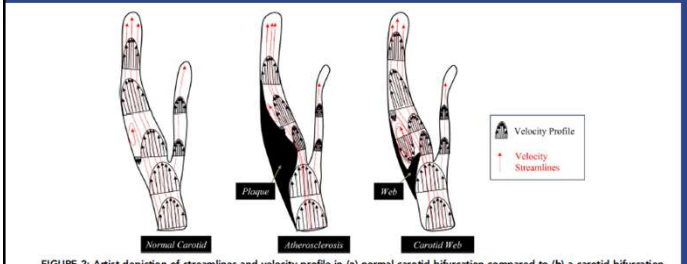

FIGURE 2: Artist depiction of streamlines and velocity profile in (a) normal carotid bifurcation compared to (b) a carotid bifurcation with an atherosclerotic lesion (c) a carotid bifurcation with a Carotid web (CaW) lesion. The larger recirculation region in patients with CaWs due to the sudden expansion.

(30)

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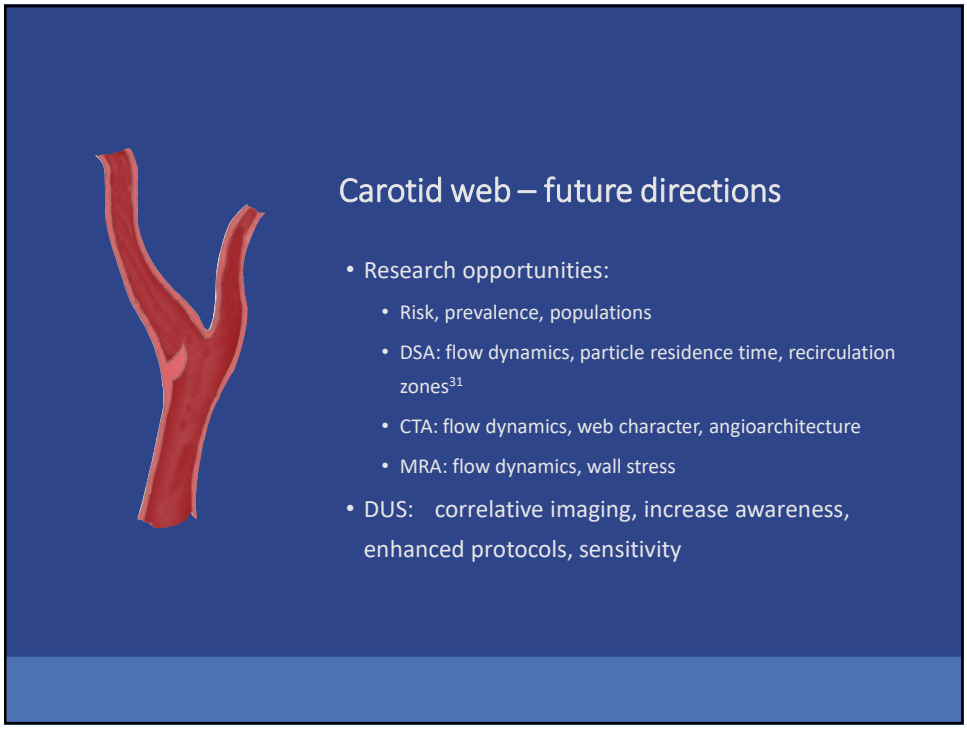

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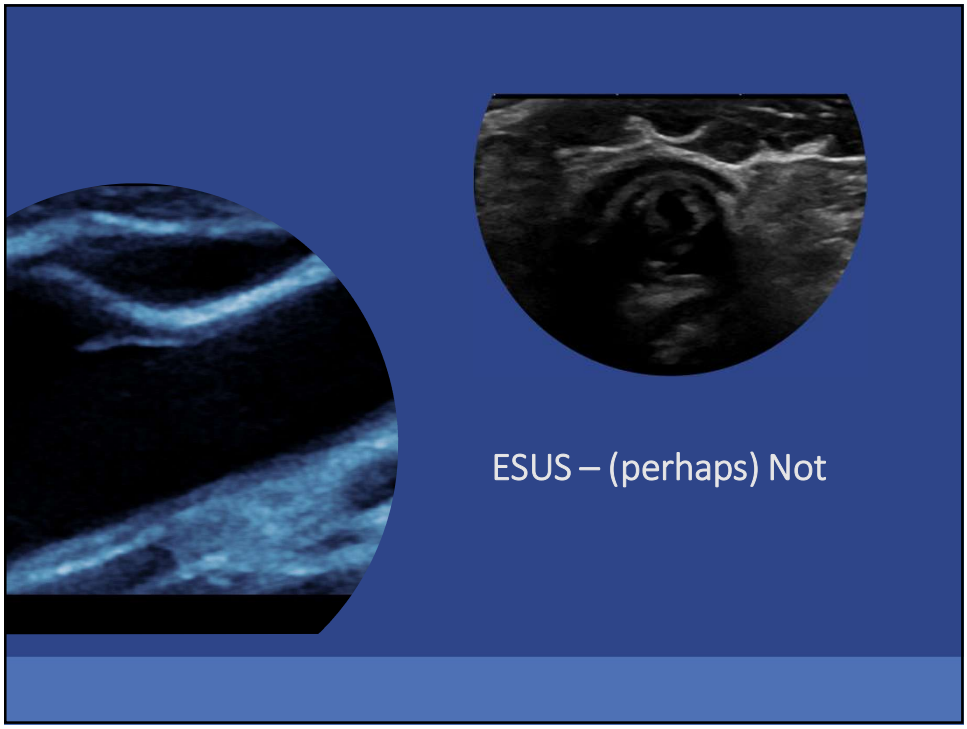

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