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Carotid Duplex and Transcranial Doppler Applications in Stroke

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Disclosures

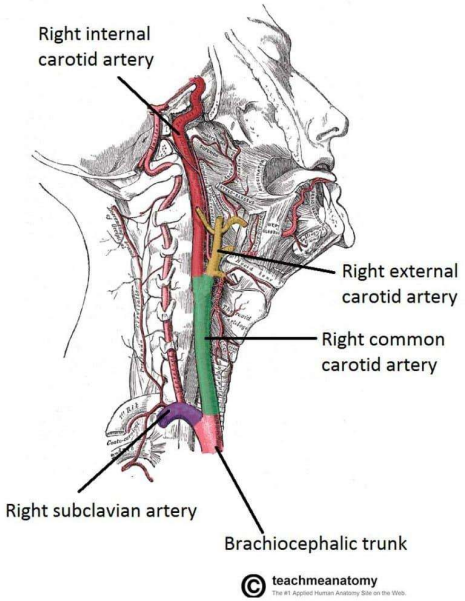
None

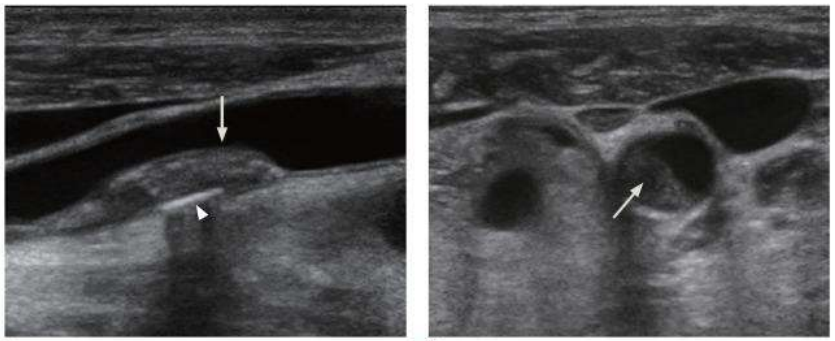
Outline and Objective

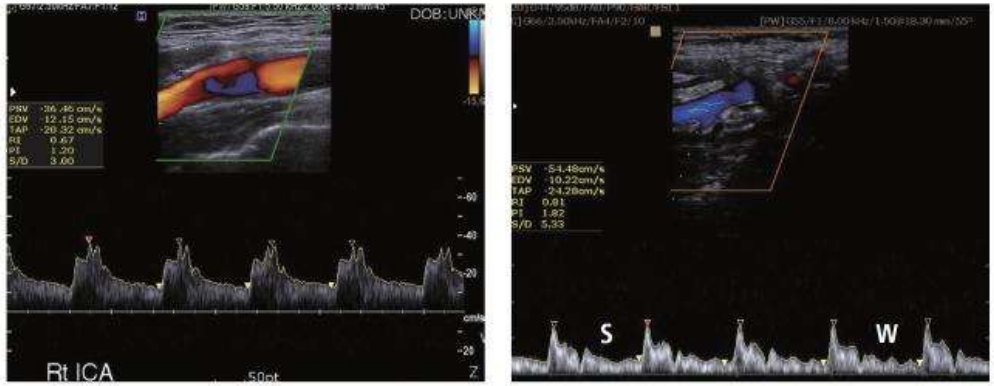
- What is carotid US and Transcranial Doppler?
- Carotid Duplex
  - Carotid Plaque-Rads 2024
    - Plaque morphology and risk
- Transcranial Doppler
  - Micro-embolic signals
  - Vasomotor reactivity
  - Hyperperfusion post-stenting
  - Post-Thrombectomy
  - Cerebral Autoregulation

Carotid Duplex

- Carotid Ultrasound
  - B-Mode (greyscale) →Plaque imaging
  - Color Doppler→ Flow and direction
  - Spectral Doppler→ PSV, EDV



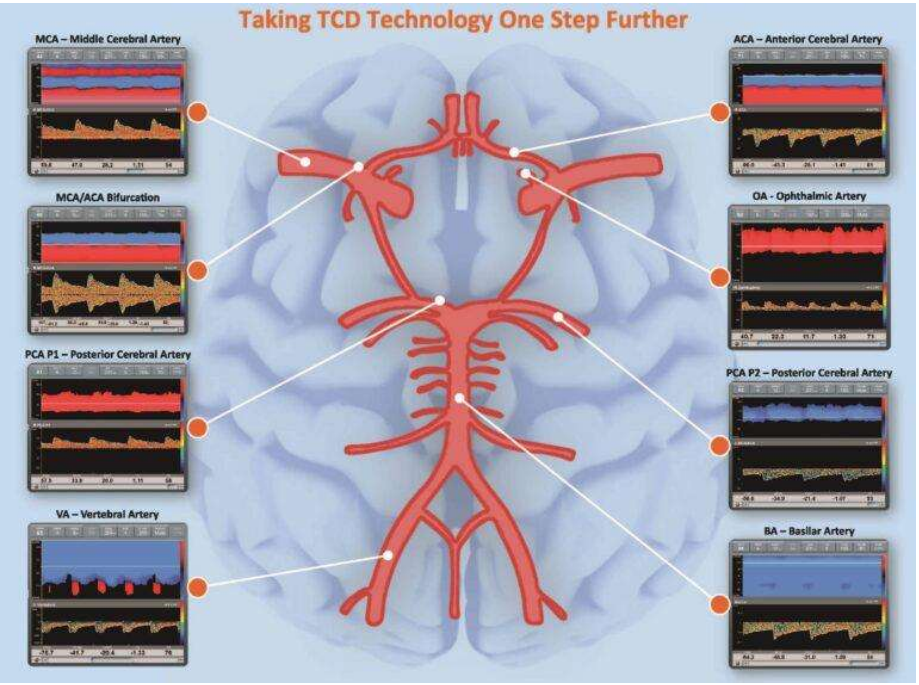


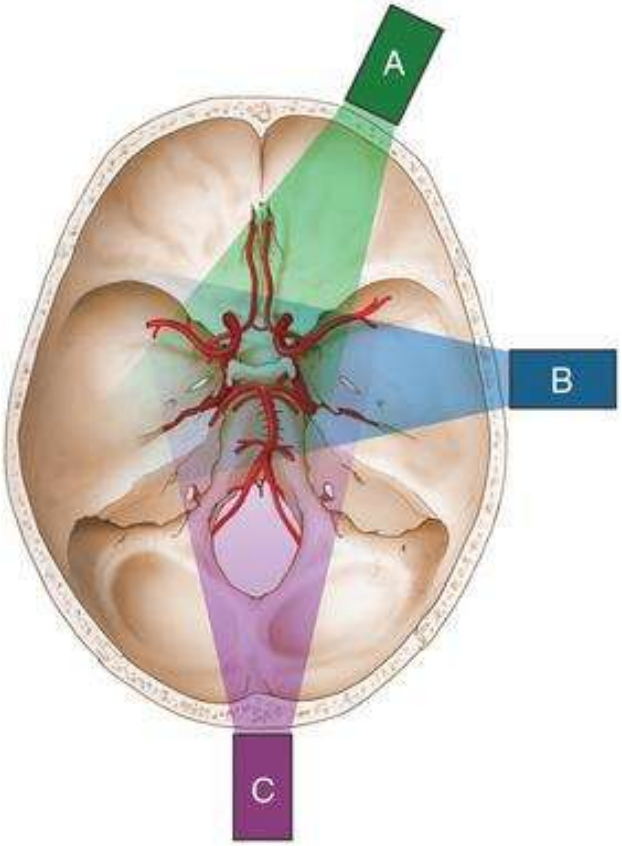


https://pmc.ncbi.nlm.nih.gov/articles/PMC4058969/figure/f3-usg-33-1-11-4/

Transcranial Doppler

- Temporal Window
- Orbital Window
- Suboccipital window





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Example Case

70 year old M with stroke like symptoms…

Our Plan: History for neurovascular symptoms, clinical examination.

But first we reviewed the Carotid duplex…

Carotid Plaque-Rads

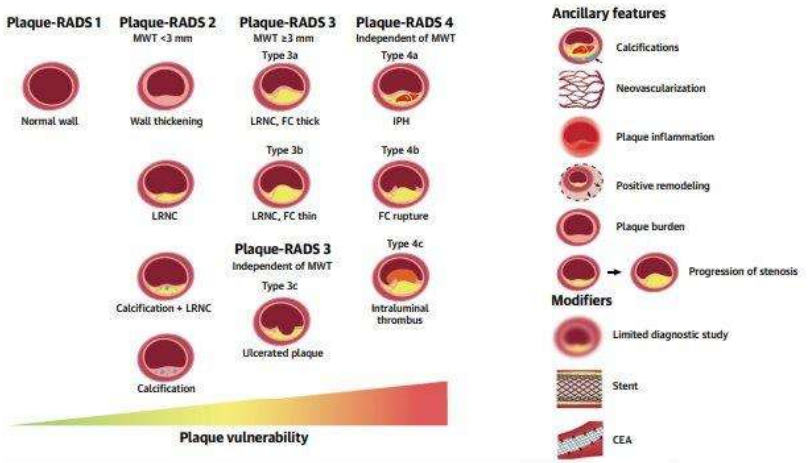
TABLE 1 Summary of Plaque-RADS Categories Based on Imaging Findings and the Attributable Risk of Developing Symptoms

Plaque-RADS Score	Attributable Risk of Ipsilateral Cerebrovascular Events	Imaging Findings
1	Absent	Normal vessel wall
2	Low	MWT <3 mm
3	Moderate	MWT ≥3 mm or Healed ulcerated plaque
3a	Moderate	LRNC with intact thick FC (MWT ≥3 mm)
3b	Moderate	LRNC with thin FC (MWT ≥3 mm)
3c	Moderate	Healed ulcerated plaque
4	High	Complicated plaque (irrespective of MWT)
4a	High	IPH
4b	High	Ruptured FC
4c	High	Intraluminal thrombus

Ancillary features: inflammation, neovascularization, positive plaque remodeling, plaque progression, calcifications. Modifiers: limited diagnostic study ("L"), presence of a stent ("Stent"), previous carotid endarterectomy ("CEA").

FC = fibrous cap; IPH = intraplaque hemorrhage; LRNC = lipid-rich necrotic core; MWT = maximum wall thickness; RADS = reporting and data system.

CENTRAL ILLUSTRATION Schematic Representation of the Different Plaque-RADS Categories 1 to 4

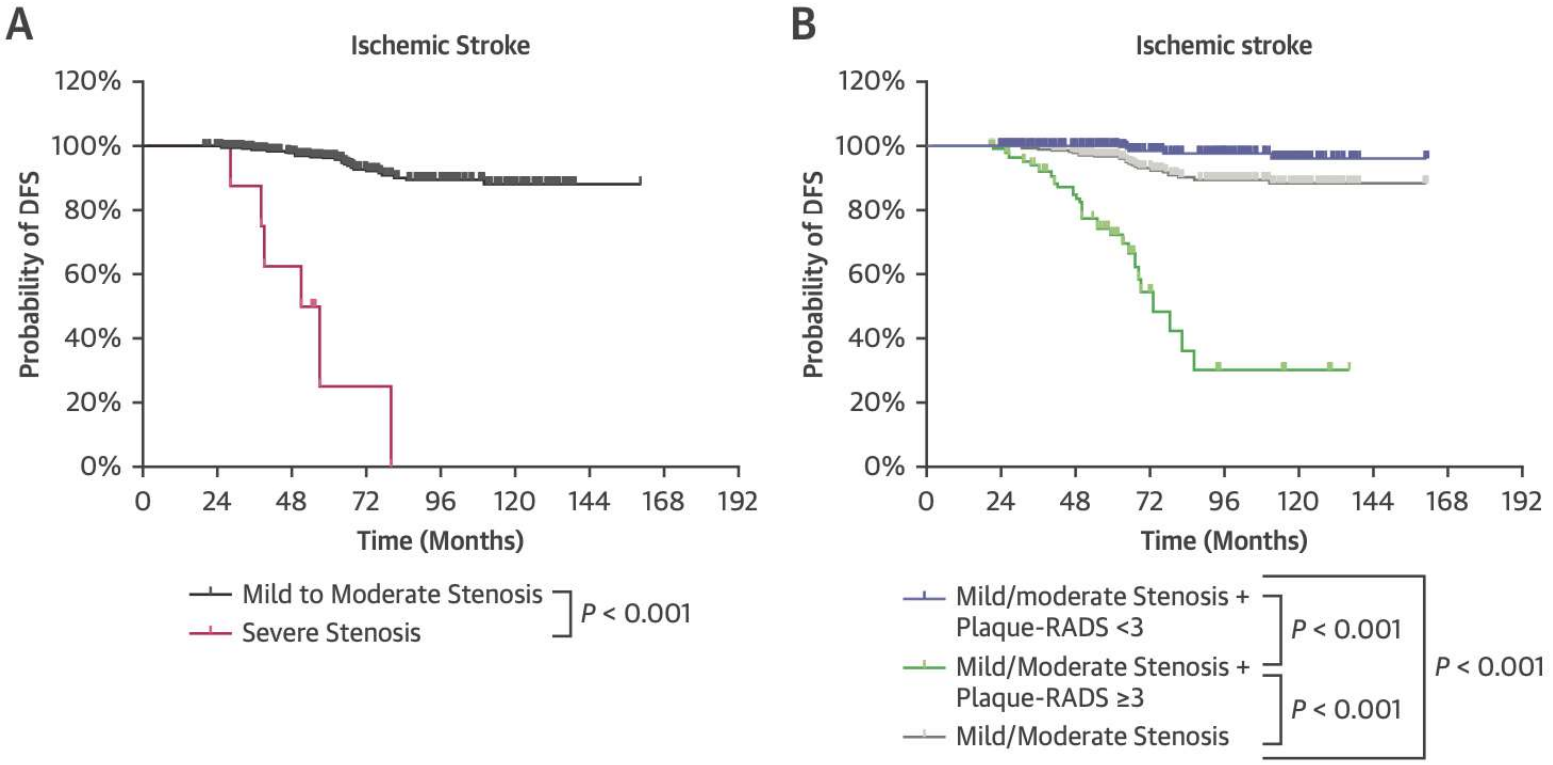


Saba L, et al. J Am Coll Cardiol Img. 2024;17(1):62-75.

CEA = carotid endarterectomy; FC = fibrous cap; IPH = intraplaque hemorrhage; LRNC = lipid-rich necrotic core; MWT = maximum wall thickness; RADS = Reporting and Data System.

JACC Cardiovasc Imaging . 2024 Jan;17(1):62-75.

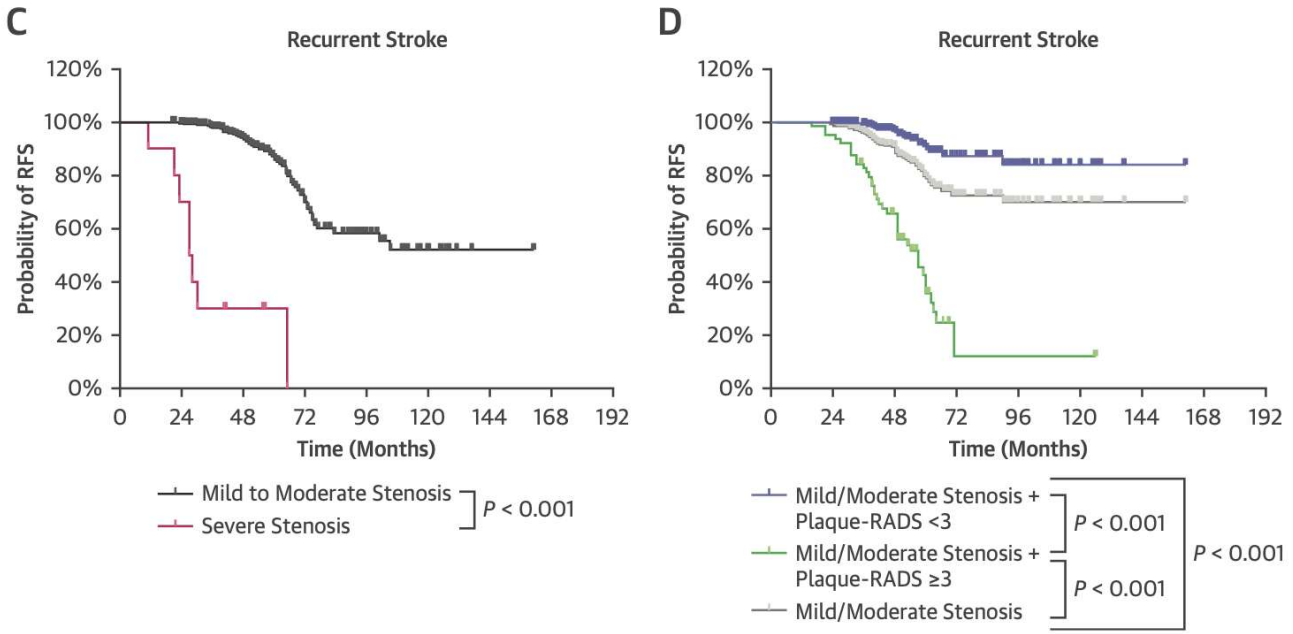
Stenosis and Plaque: Ischemic Stroke



DFS= Disease free survival (time to initial occurance), Mild = <30%, Moderate 31-69%, Severe 70-99%.

Zhe Huang, Xue-Qing Cheng, Rui-Rui Lu, Xiao-Jun Bi, Ya-Ni Liu, You-Bin Deng, Incremental Prognostic Value of Carotid Plaque–RADS Over Stenosis Degree in Relation to Stroke Risk, JACC: Cardiovascular Imaging, 2024,

Carotid stenosis and Plaque: Recurrent Stroke

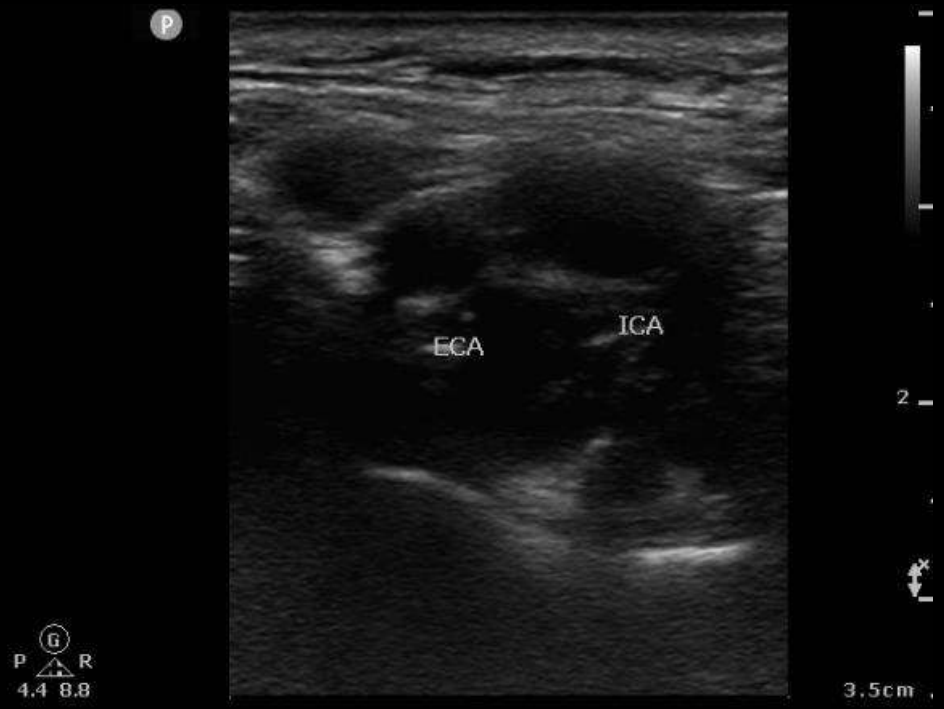


RFS= Recurrence-free survival, Mild = <30%, Moderate 31-69%, Severe 70-99%.

Zhe Huang, Xue-Qing Cheng, Rui-Rui Lu, Xiao-Jun Bi, Ya-Ni Liu, You-Bin Deng, Incremental Prognostic Value of Carotid Plaque–RADS Over Stenosis Degree in Relation to Stroke Risk, JACC: Cardiovascular Imaging, 2024,

Plaque-Rads 1

No plaque= No Risk



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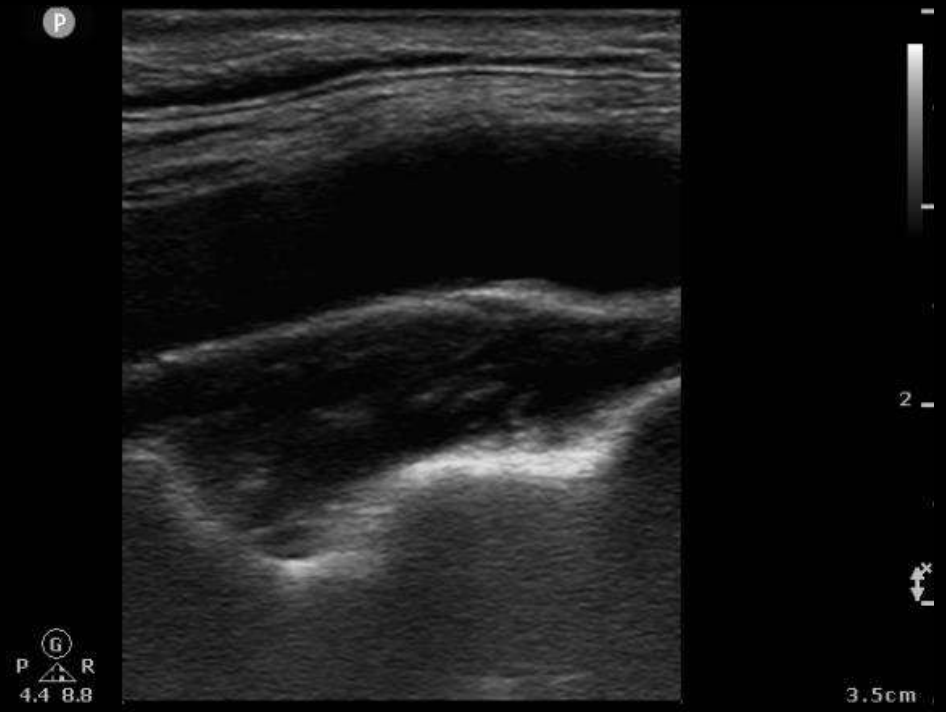
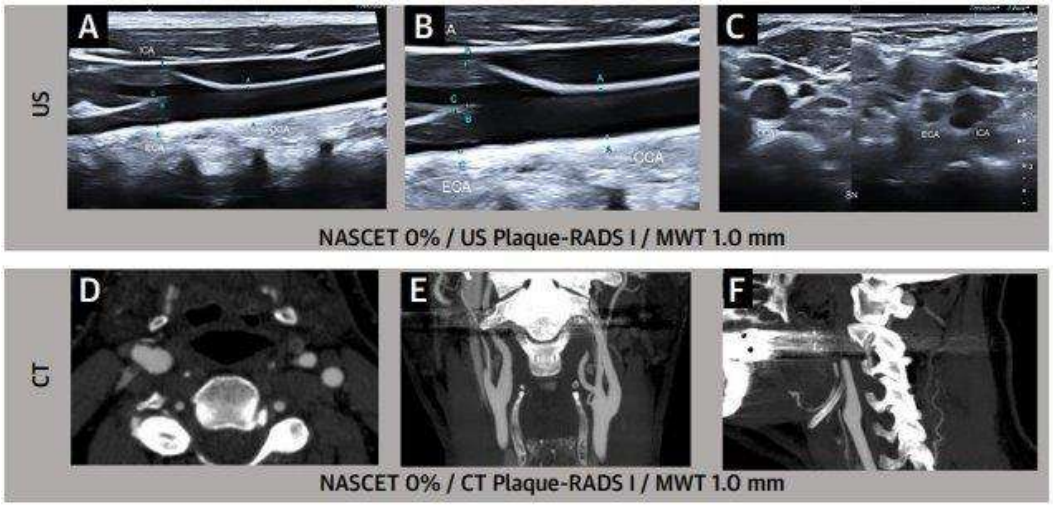


L PROX ICA

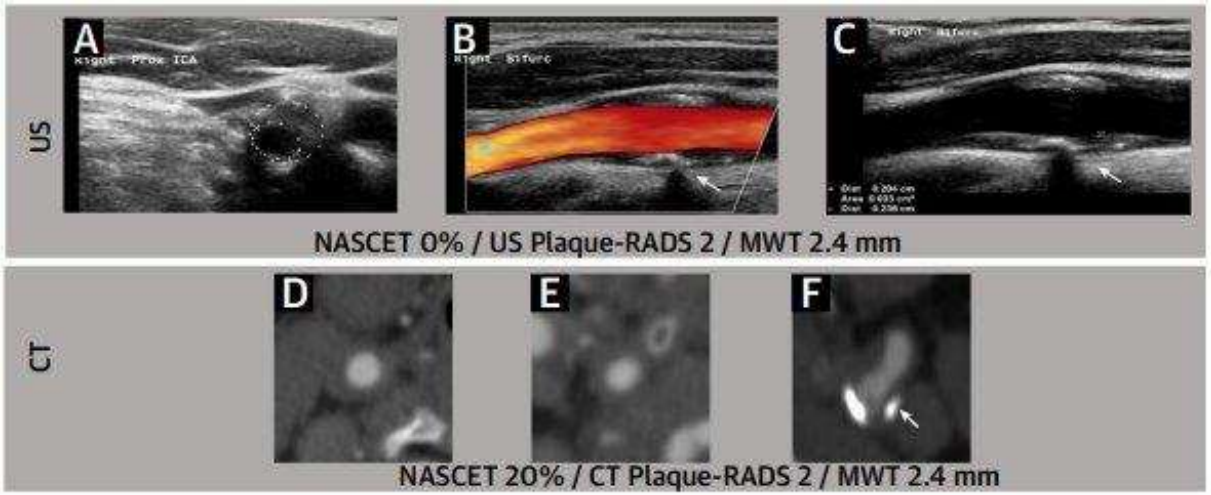
Plaque-Rads 1



Patient's without evidence of carotid plaque are not at risk of stroke. [1-4]

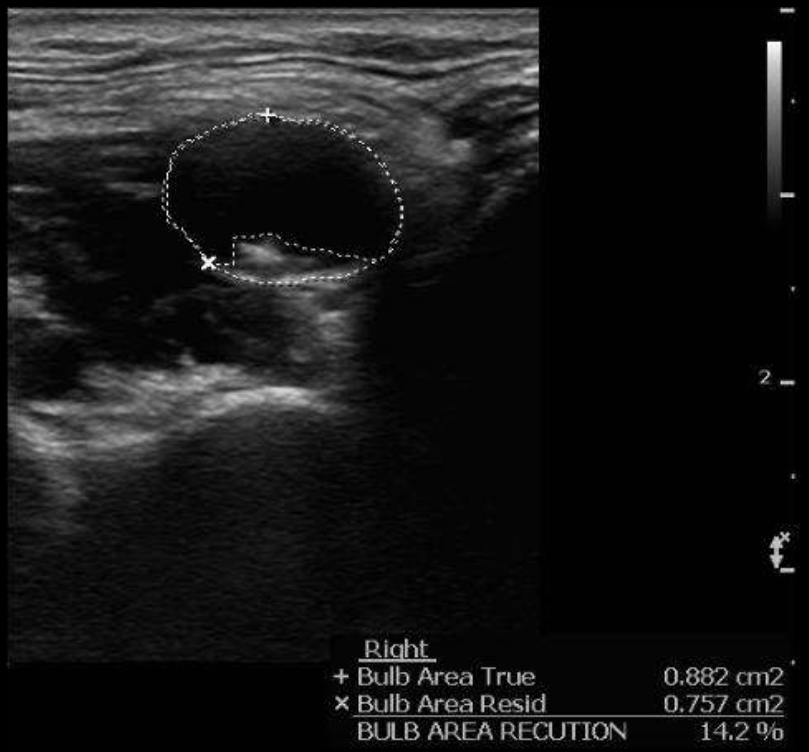
Example Carotid Duplex

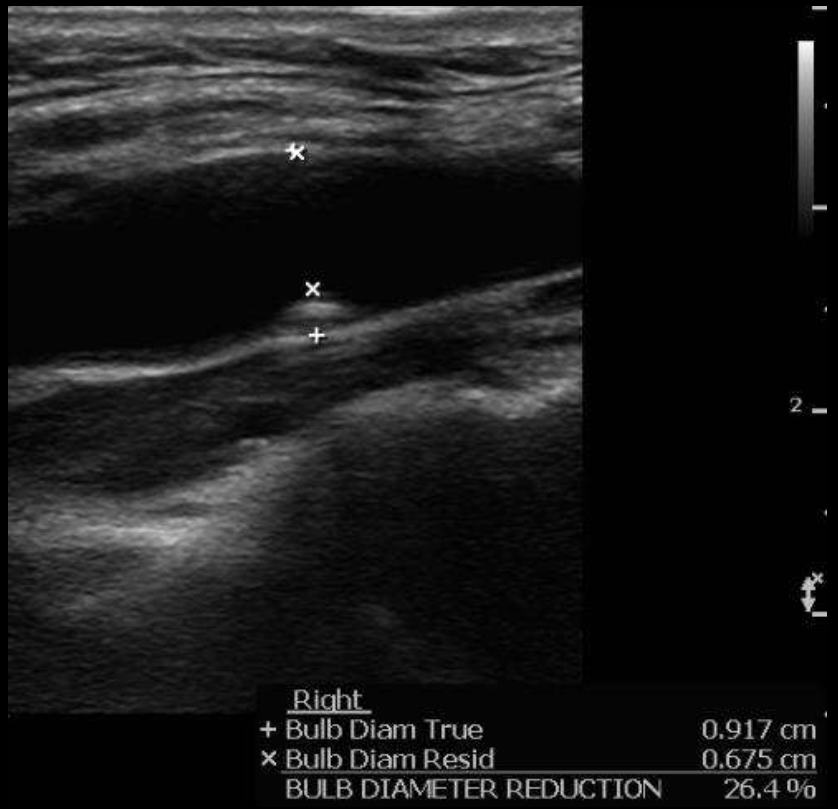
Plaque-Rads 2



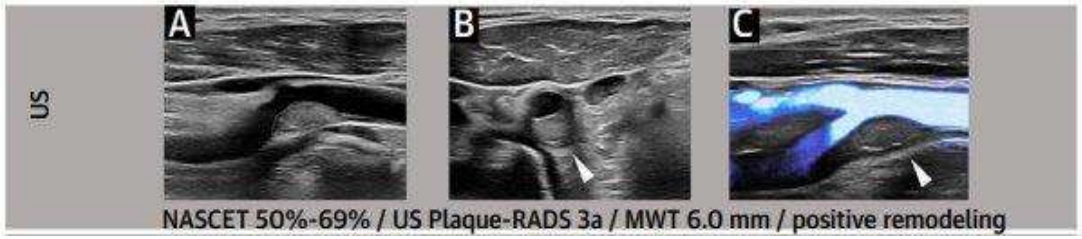
- Plaque-Rads 2
- Maximal wall thickness (MWT) <3mm without complicated plaque.
  - Risk Low
  - Think "small" LRNC

Plaque Rads 2 Example

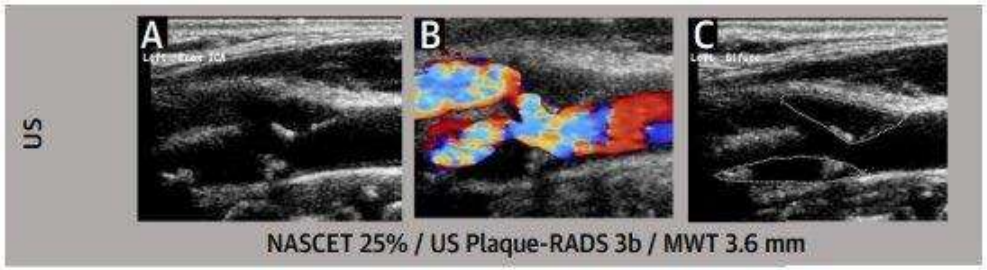




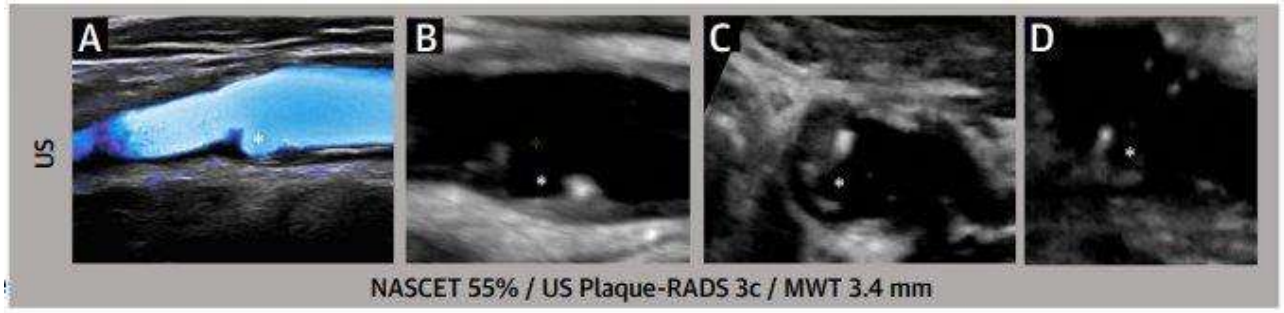
Plaque Rads 3



NASCET 50%-69% / US Plaque-RADS 3a / MWT 6.0 mm / positive remodeling



NASCET 25% / US Plaque-RADS 3b / MWT 3.6 mm



NASCET 55% / US Plaque-RADS 3c / MWT 3.4 mm

Plaque-Rads 3a

- >3mm MWT, no complicated features.
  - Ex: uniform moderate-large LRNC with thick/intact fibrous cap.

Plaque-Rads 3b

- >3mm MWT, no complicated features.
  - Same as above but Thin fibrous cap.

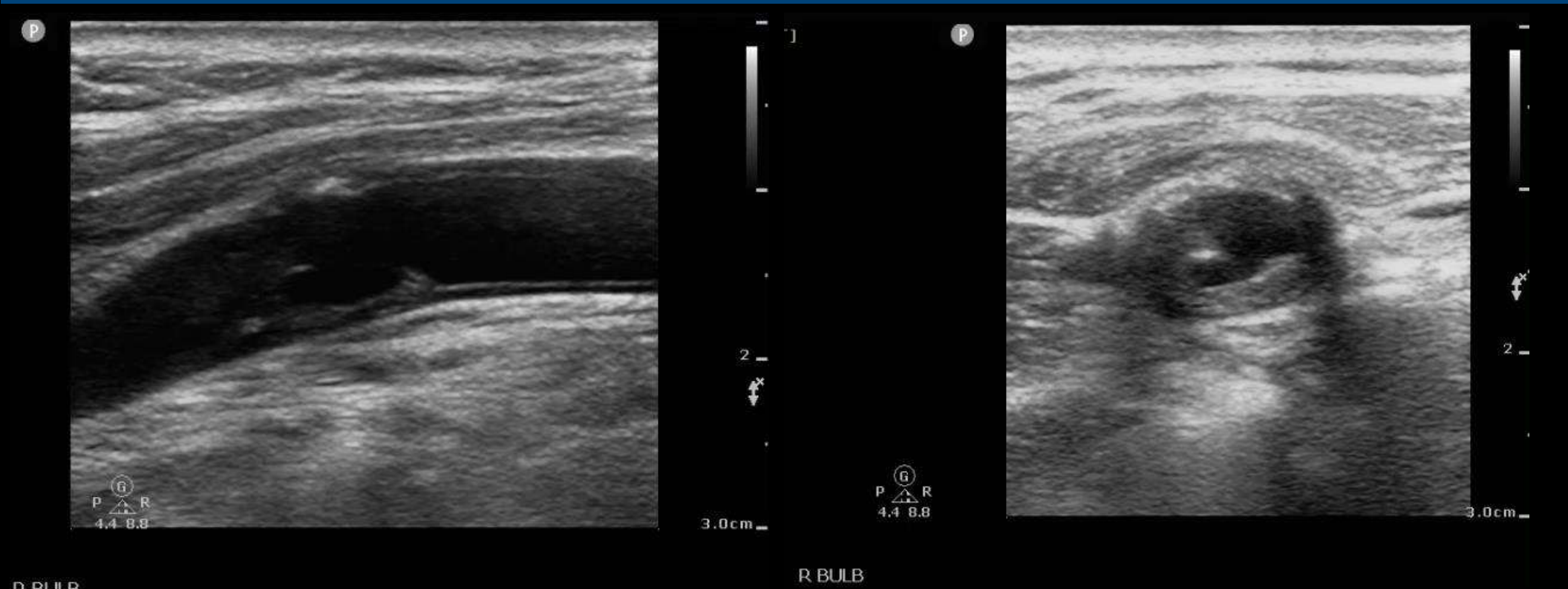
Plaque-Rads 3c

- Plaque ulceration- without IPH, thrombus or FC disruption.
  - Ex: Ulcerated plaque without complicating features.

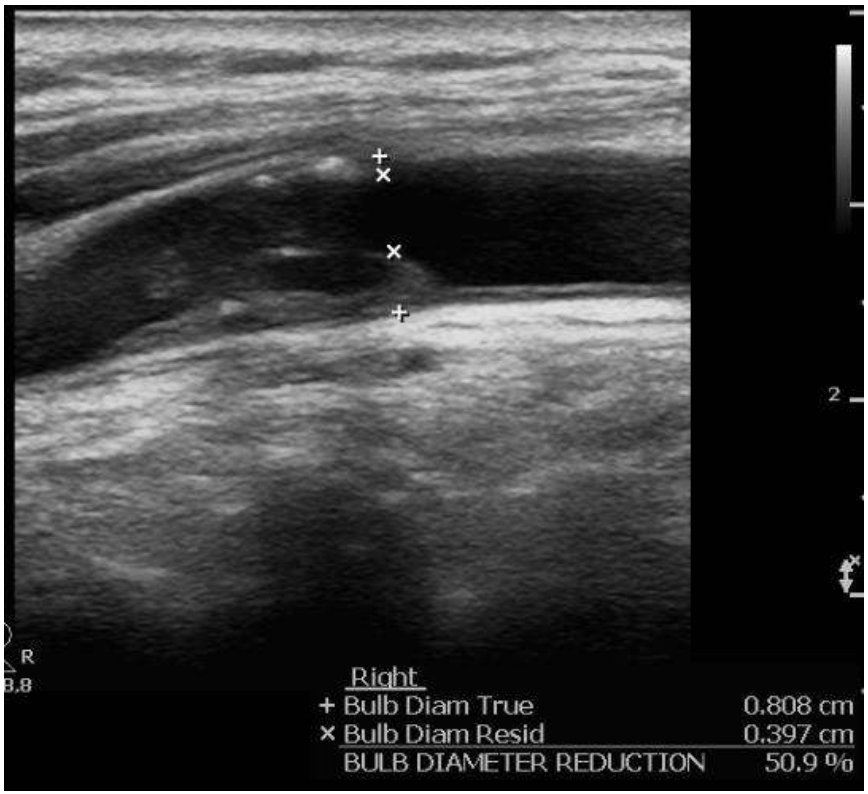
Plaque Rads 3a Examples

MWT >3mm,
Moderate to large LRNC,
Thick or indistinguishable FC,
Calcifications.

Plaque-Rads 3c Ulcerated Plaque

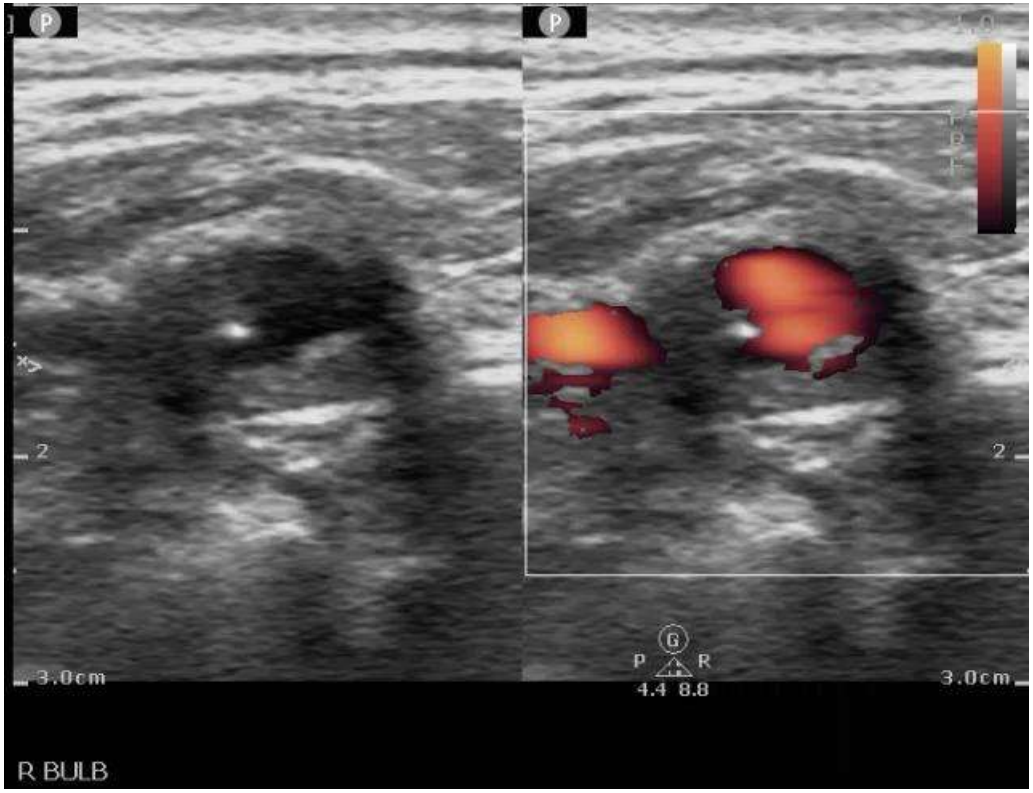


Plaque rads 3b Intact cap



MWT >3mm,
Moderate to large LRNC with,
THIN cap.

Plaque-Rads 3c Ulcerated Plaque



Ulcerated Plaque independent of MWT.

Can have calcifications and LRNC.

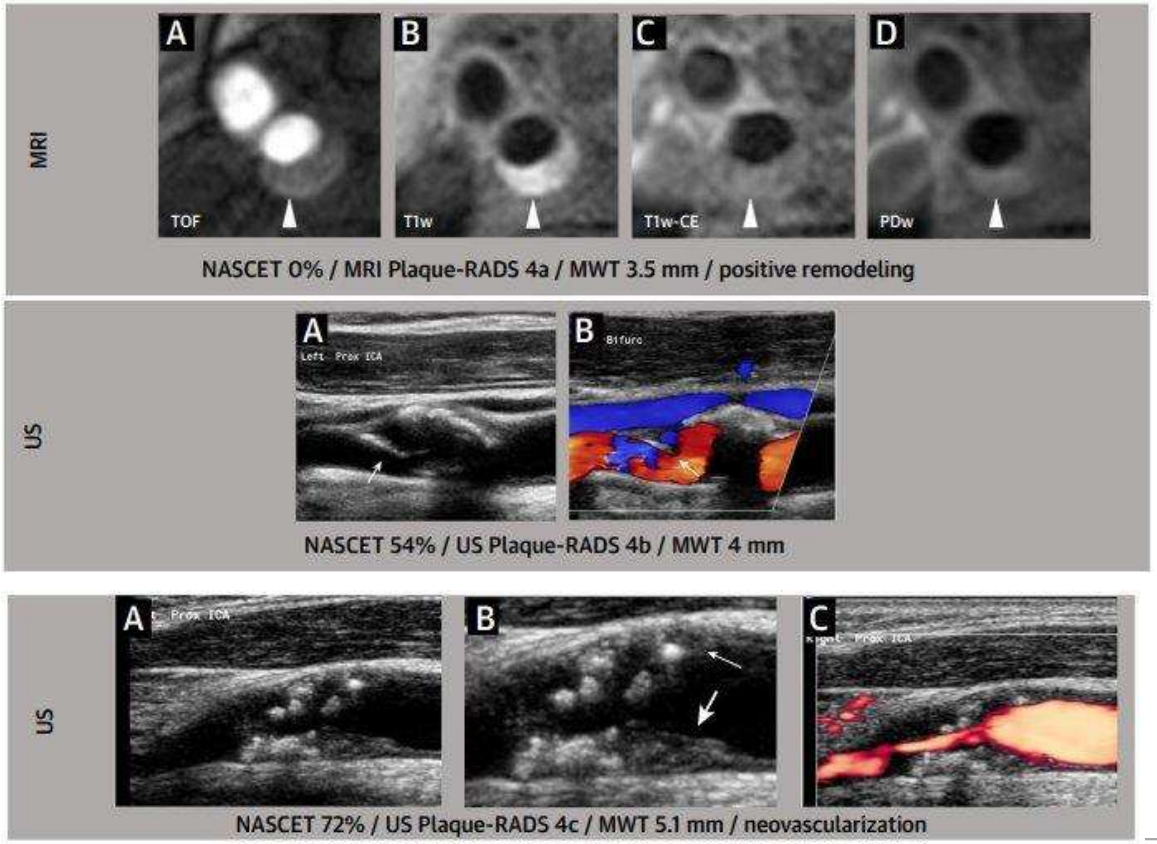
Example Case

70 year old M smoker, never seen a physician.

MRI Brain finds silent infarction

But first we reviewed the Carotid duplex…

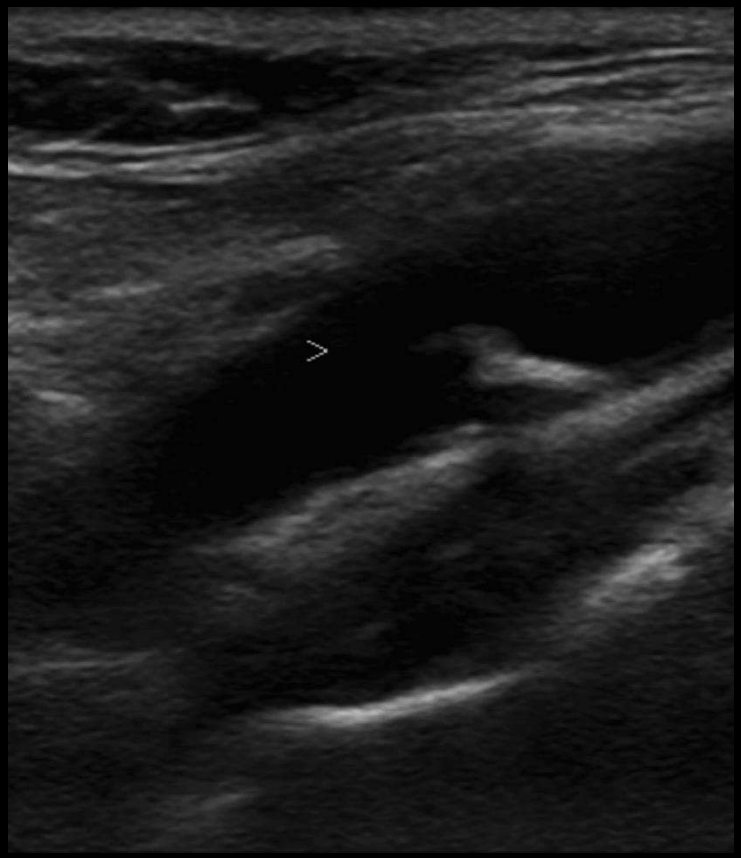
Plaque Rads 4



Plaque-Rads 4
Independent of plaque thickness:

- IPH
- Ruptured Fibrous cap
- Intraluminal thrombus

Example Case (mobile thrombus carotid doppler)



Transcranial Doppler: Emboli Detection

Asymptomatic embolisation for prediction of stroke in the Asymptomatic Carotid Emboli Study (ACES): a prospective observational study

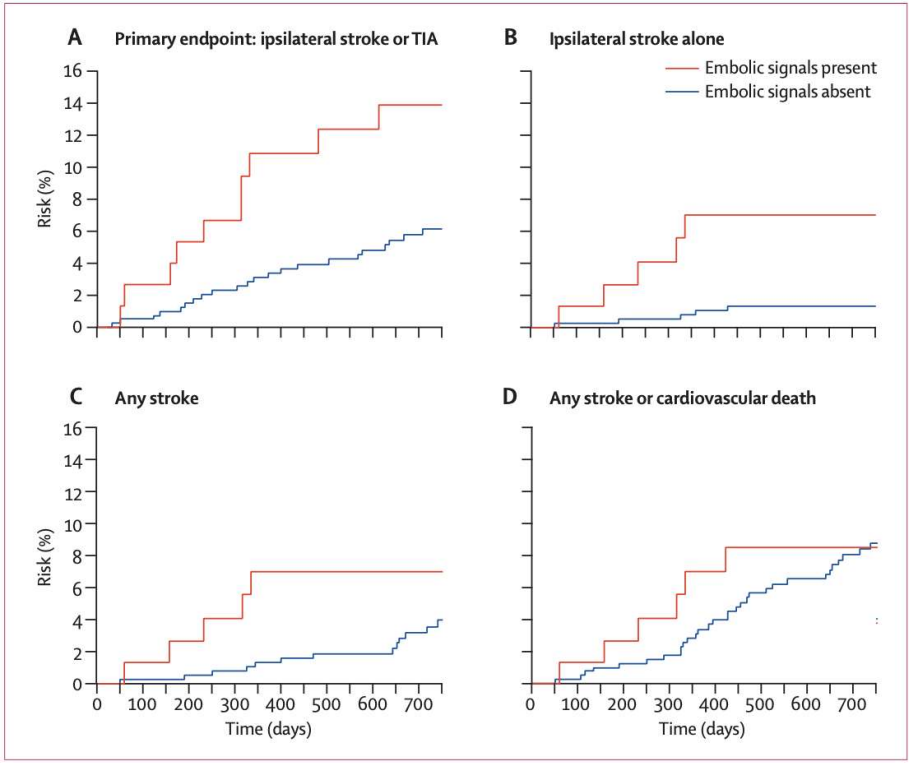
Hugh S Markus, Alice King, Martin Shipley, Raffi Topakian, Marisa Cullinane, Sheila Reihill, Natan M Bornstein, Arjen Schaafsma

Design:

- Prospective multi-center observational trial.
- Asymptomatic carotid stenosis (ACS) – 70%.
- 2x 1 hour recordings at baseline (ipsilateral MCA).
- 1 hour at 6, 12 and 18 months.
- End point ipsilateral stroke or TIA.

Results

- With embolic signal compared to those without HR from baseline to 2 years:
  - Stroke or TIA, 2.54 (95% CI 1·20–5·36; p=0·015).
  - Stroke alone, 5.57 (1·61–19·32; p=0·007).
- Absolute annual risk of stroke or TIA
  - Stroke or TIA: 7·13% with embolic signals, 3·04% in those without.
  - Stroke alone: 3·62% with embolic signal, 0·70% in those without.



Markus HS, King A, Shipley M, *et al* Asymptomatic embolisation for prediction of stroke in the Asymptomatic Carotid Emboli Study (ACES): a prospective observational study. Lancet Neurol 2010;9:663–71

Transcranial Doppler: Emboli Detection

Effects of Intensive Medical Therapy on Microemboli and Cardiovascular Risk in Asymptomatic Carotid Stenosis

ARCHIVES EXPRESS

J. David Spence, MD; Victoria Coates, BA, HBSc; Hector Li, MD; Arturo Tamayo, MD; Claudio Muñoz, MD, PhD; Daniel G. Hackam, MD, PhD; Maria DiCicco, RVT; Janine DesRoches, RVT; Chrysi Bogiatzi, MD; Jonathan Klein, MD; Joaquim Madrenas, MD, PhD; Robert A. Hegele, MD

Design:

- Prospective Observational trial.
- Asymptomatic carotid stenosis (ACS).
- Compared Emboli, CV events, carotid plaque progression (CPP), and medical therapy.

Results

- 199 enrolled 2000-2002.
  - Emboli: 12.6%
  - Stroke, MI, death or CEA: 17.6%
  - CPP at 1 year f/u: 69 mm2

- 269 enrolled 2003-2007
  - Emboli: 3.7%
  - Stroke, MI, death or CEA: 5.6%
  - CPP at 1 year f/u: 23 mm^2

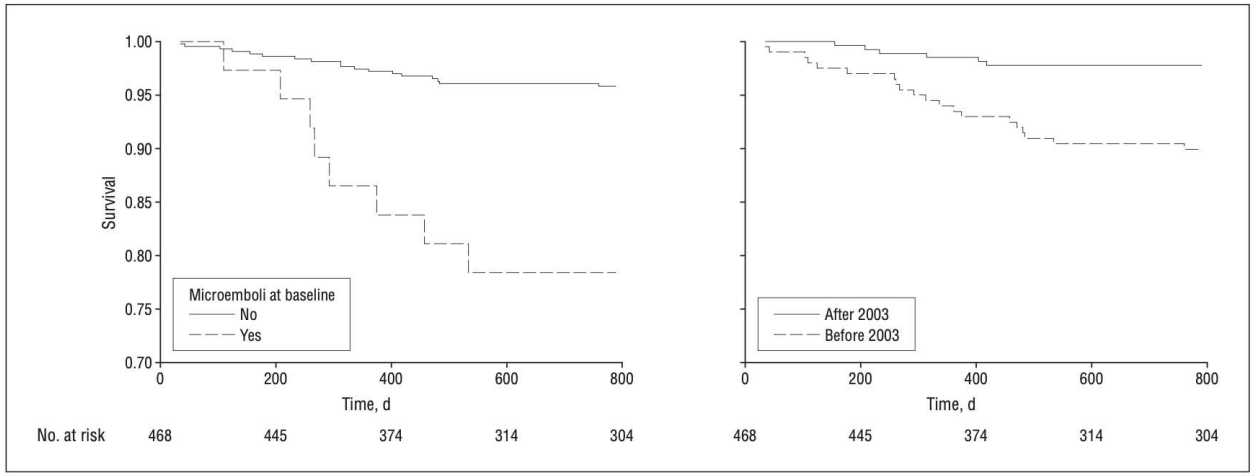
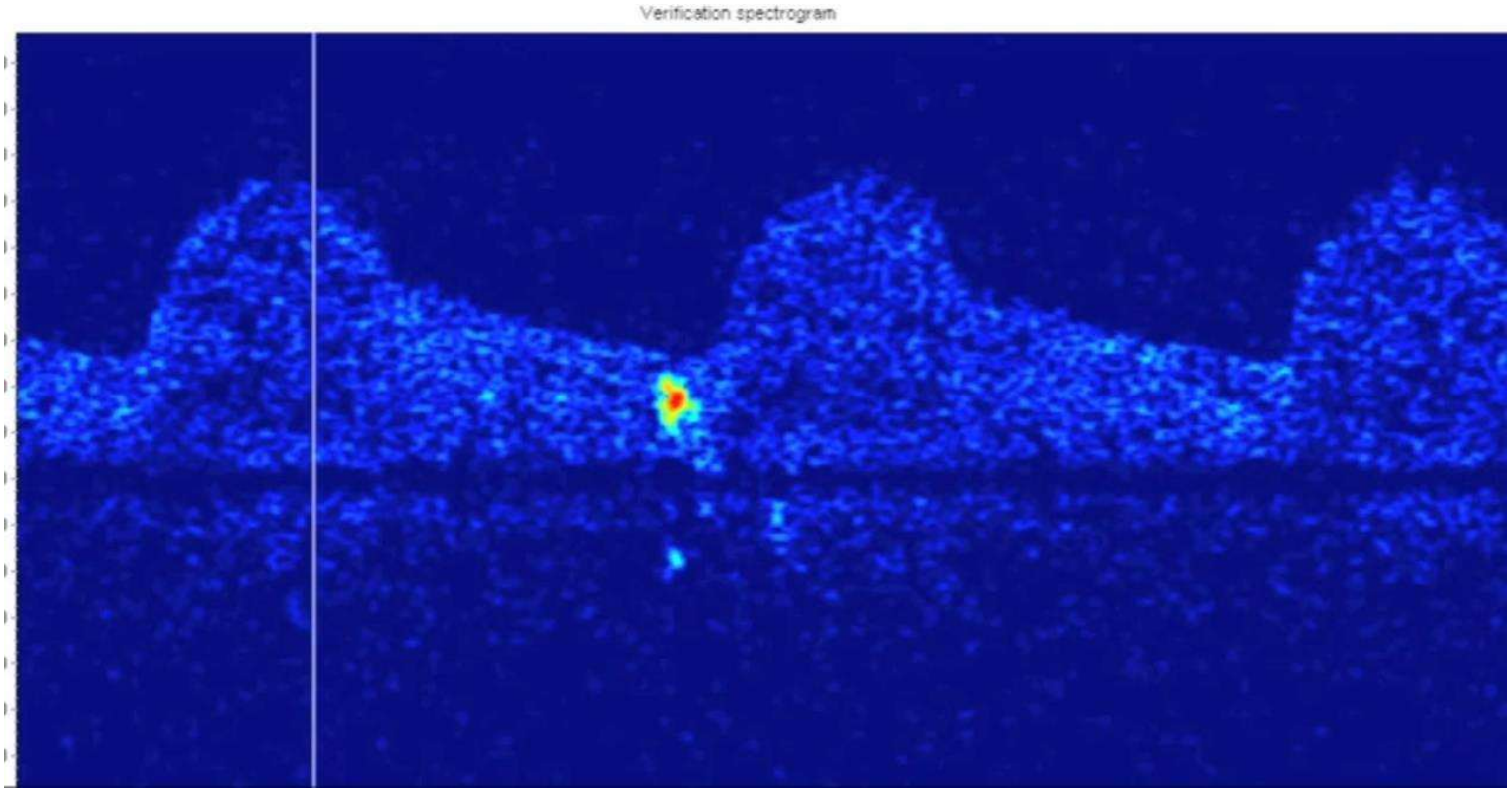


Figure 2. Kaplan-Meier survival plots by year of entry into the study and presence or absence of microemboli at baseline. Survival free of stroke, death, or myocardial infarction was significantly better for patients entering the study after 2003 and for patients without microemboli at baseline (log-rank test, $P<.001$ for both).

Spence JD, Coates V, Li H, *et al* Effects of intensive medical therapy on microemboli and cardiovascular risk in asymptomatic carotid stenosis. Arch Neurol 2010;**67**:180–6.

TCD Emboli Monitoring

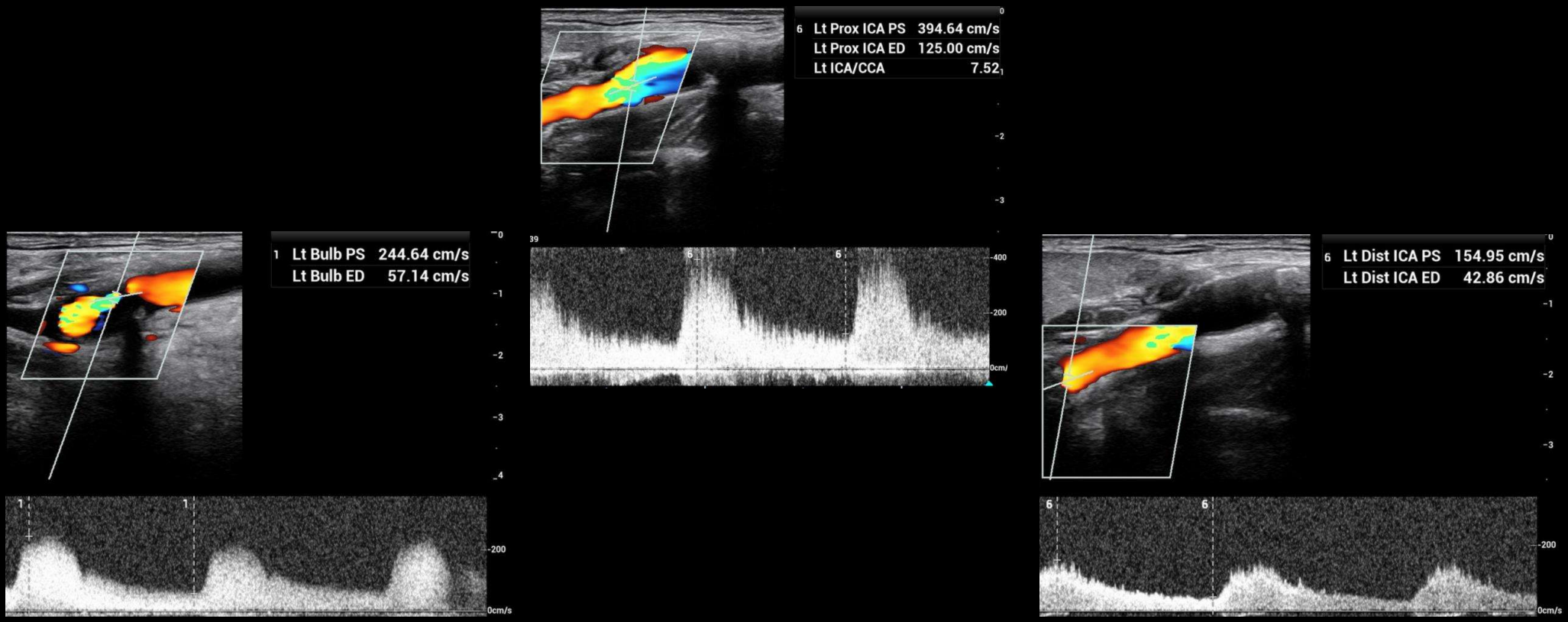


Example case

70 year old M smoker, never seen a physician.

MR Brain with watershed infarction on left.

Example Case



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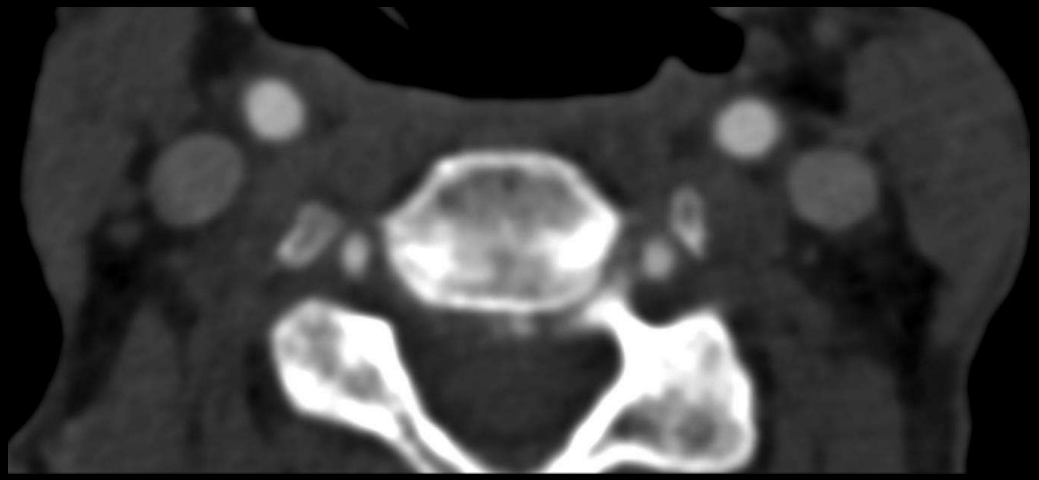
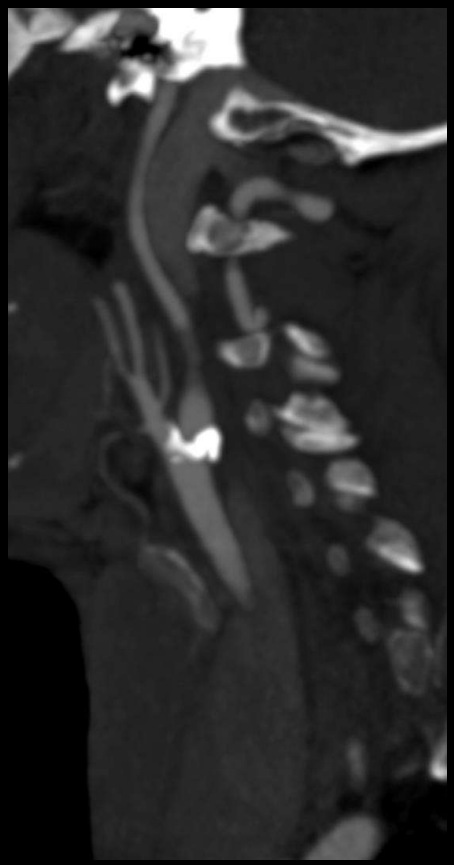




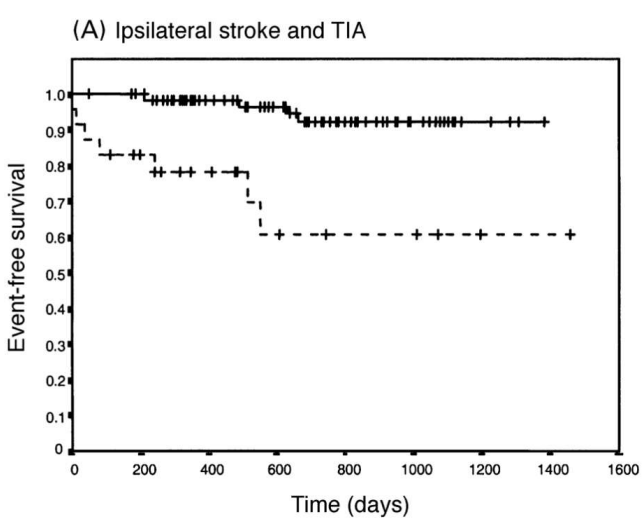
Transcranial Doppler: Vasomotor Reactivity

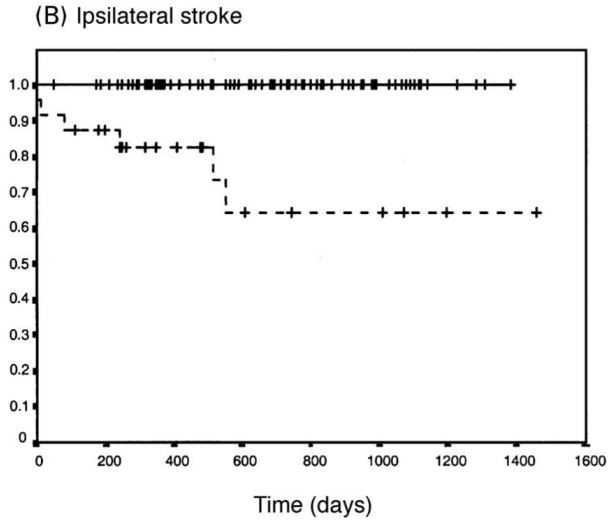
Brain (2001), **124**, 457–467

Severely impaired cerebrovascular reactivity predicts stroke and TIA risk in patients with carotid artery stenosis and occlusion

Hugh Markus and Marisa Cullinane

- Methods:
  - Prospective observational study
  - Reactivity of MCA to 8% CO2
    - >20% Increase in MCA velocity
  - 48 with carotid Occlusion, 59 >70% stenosis
  - End point: TIA, Stroke, Death or study end
- Results
  - 11 Events (6 Stroke, 5 TIA)
  - Predicted Stroke and TIA in whole group (p=0.00001)
  - Carotid occlusion alone (p=0.019), Carotid stenosis (p=0.015)
  - Independent predictor OR 14.4 (95% confidence interval 2.63–78.74, *P* 0.0021)





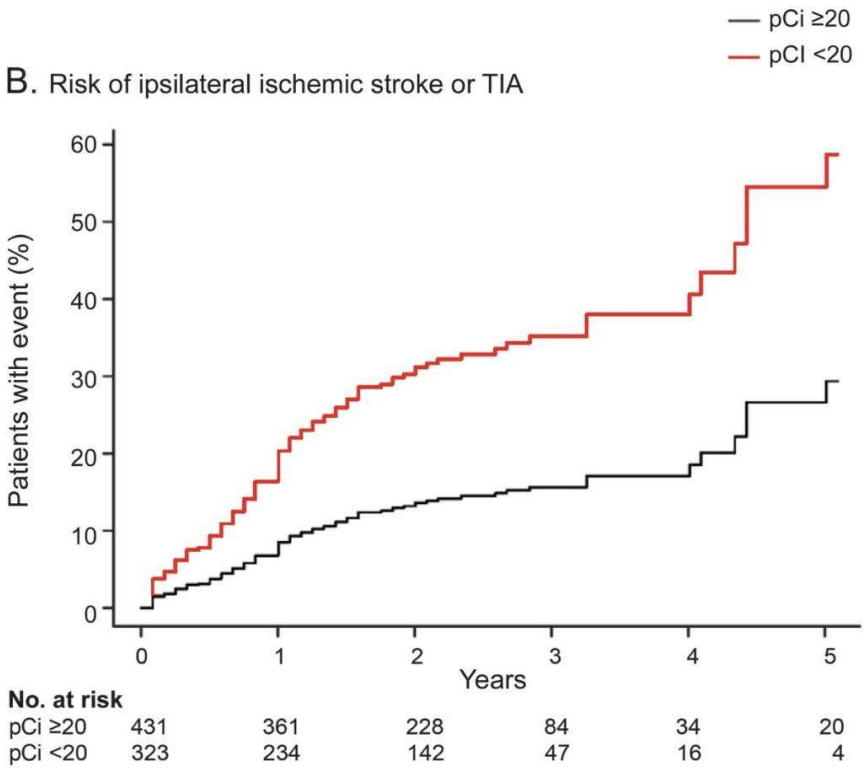
Brain (2001), 124,457-476

Cerebrovascular reactivity predicts stroke in high-grade carotid artery disease

- Methods
  - Meta-Analysis of prospective studies of TCD CVR studies for prediction of ipsilateral stroke.
  - Percentage of CBF velocity increase during hypercapnia.
  - Impaired if <20% Increase

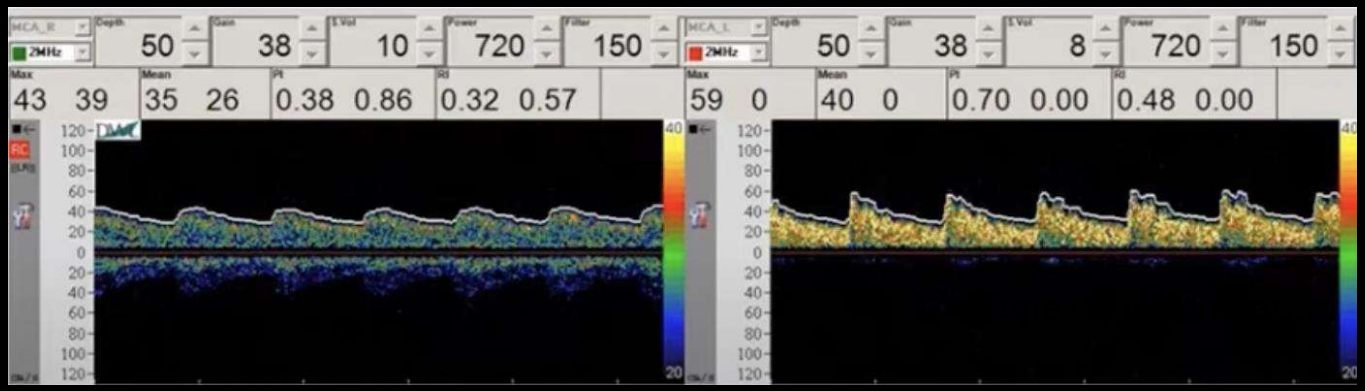
- Results
  - 754 patients, 9 Studies
  - Impaired CO2 reactivity independent factor
    - HR 3.69 (2.01-6.77, p=0.0001)
  - Similar between symptomatic and asymptomatic patients

↑ Risk, HR 1.64 ↓ Per 10% decrease



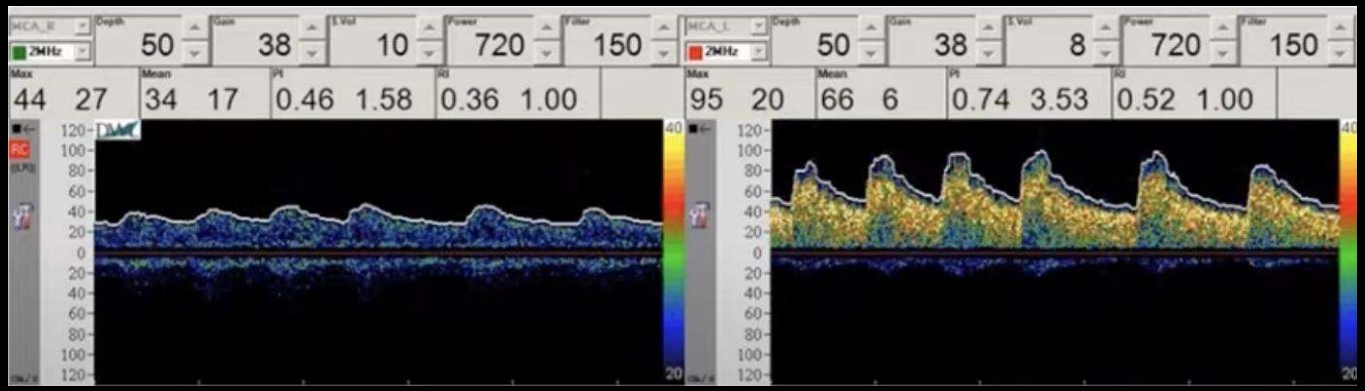
Neurology 2014 Vol. 83 Issue 16 Pages 1424-31

Cerebrovascular Reactivity Study



$$VMR\% = \frac{MFV(after) - MFV\ (before)}{MFV\ (before)} x100$$

$$Right: 65\% = \frac{66 - 40}{40} x100$$



$$Left: ??= \frac{34 - 35}{35} x100$$

Exhausted, possible steal phenomenon

Example case

70 year old M smoker, never seen a physician. May have had single episode of weakness when standing quickly but can't remember which side.

- Ultrasound with severe left carotid stenosis
- Exhausted Vasomotor reserve on left
- Stent placed

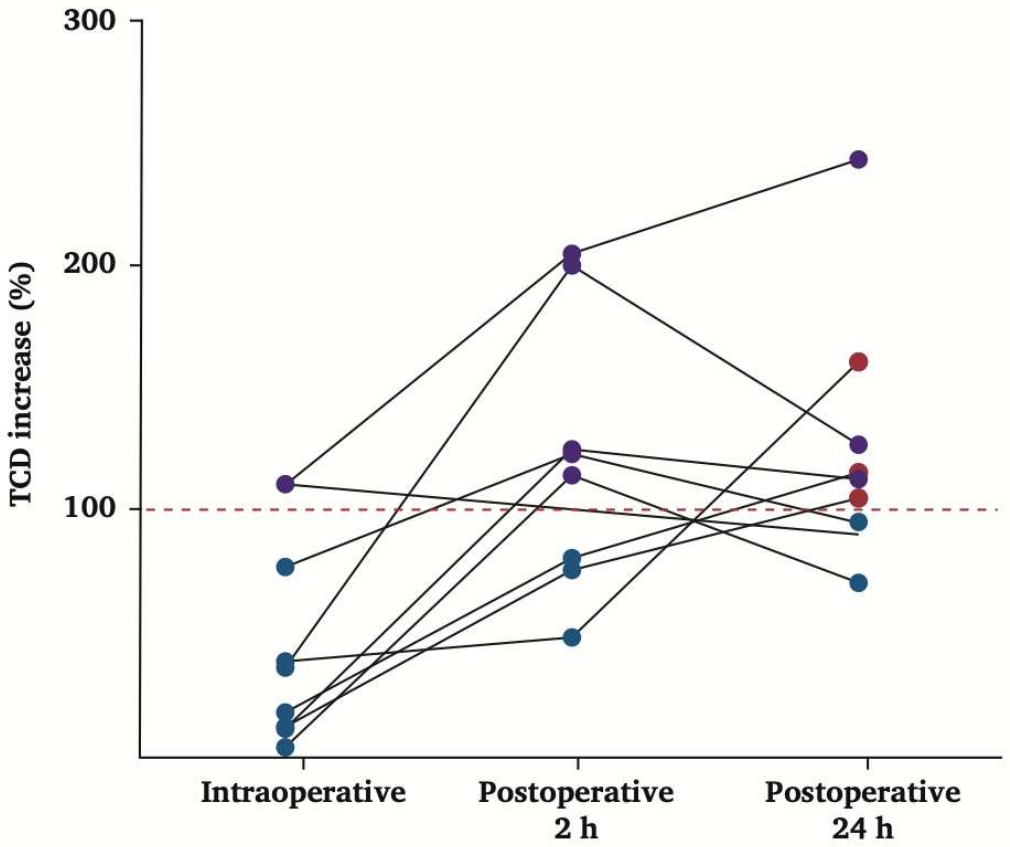
In ICU

- Monitored with TCD for hyper perfusion

Transcranial Doppler 24 Hours after Carotid Endarterectomy Accurately Identifies Patients Not at Risk of Cerebral Hyperperfusion Syndrome

Leonie M.M. Fassaert [a], Rogier V. Immink [b], Daniël J. van Vriesland [c], Jean-Paul P.M. de Vries [d,h], Raechel J. Toorop [a], L. Jaap Kappelle [e], Jan Westerink [f], Selma C. Tromp [g], Gert J. de Borst [a,*]

- Methods:
  - Retrospective analysis
  - CEA patients with Intra-and post-op TCD
  - Intra-op MFV compared to 2h and 24 hour post-op MFV
  - CH defined as >100% increase in MFV
  - CHS is above + Neurologic symptoms
- Results
  - 257 patients
  - **CH**: 25 (9.7%) intra-op, 45 (17.5%) post-op 2h, 34 (13.2%) post-op 24h
  - **CHS:** 9 (3.5%). Intra-op – 2, Post-op (2h) - 5, post-op (24) - 6
  - NPV: 97%, 98%, and 99% respectively

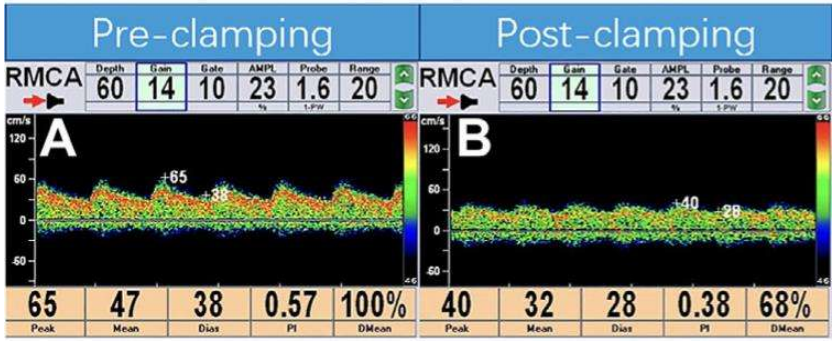


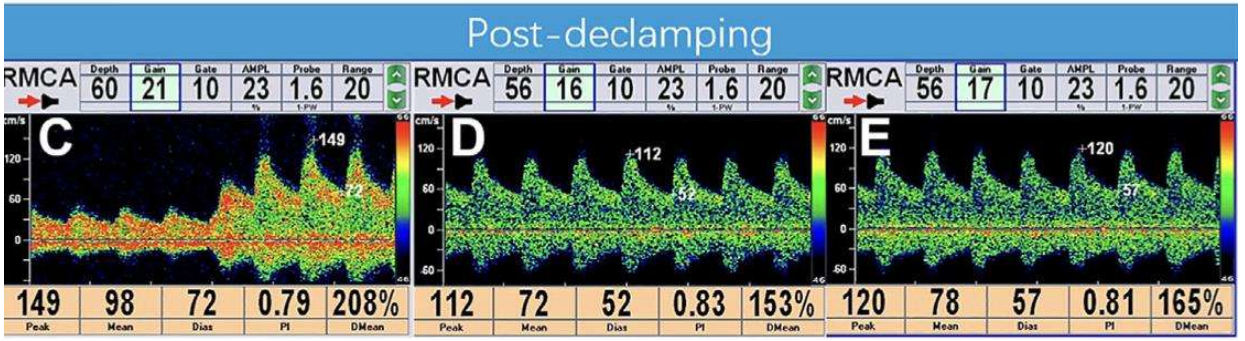
Eur J Vasc Endovasc Surg 2019 Vol. 58 Issue 3 Pages 320-327

Intraoperative Transcranial Doppler Monitoring Predicts the Risk of Cerebral Hyperperfusion Syndrome After Carotid Endarterectomy

Qiuping Li[1], Yang Hua[1,4], Jiabin Liu[2], Fubo Zhou[1,4], Liyong Du[1], Jingzhi Li[1], Qing Li[1], Liqun Jiao[3]

- Methods
  - Retrospective
  - Intra-op TCD monitoring of CEA patients
  - MFV% increase at post-clamp, post-clamp + 5min, and suturing
  - Compared CHS and non-CHS patients
- Results
  - CHS 31 (3.2%) patients, 11 with ICH
  - CHS group 177% (81%-275%), 90% (41%-175%), and 107% (55%-191%)
  - Non-CHS group 40% (14%-75%), 15% (1%-36%), and 18% (3%-41%), respectively, all P < 0.001).





World Neurosurg 2022 Vol. 165 Pages e571-e580

Example Case

70 year old M with history of atrial fibrillation presents with,

- Right sided weakness
- Speaking difficulty

Treated with IV TNK

and

TICI 2b mechanical thrombectomy

Transcranial Doppler Post Thrombectomy

A Prospective Study to Investigate Controlling Blood Pressure Under Transcranial Doppler After Endovascular Treatment in Patients With Occlusion of Anterior Circulation

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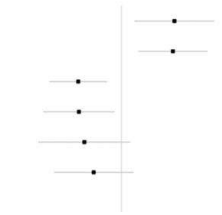
Propensity–score matched cohort

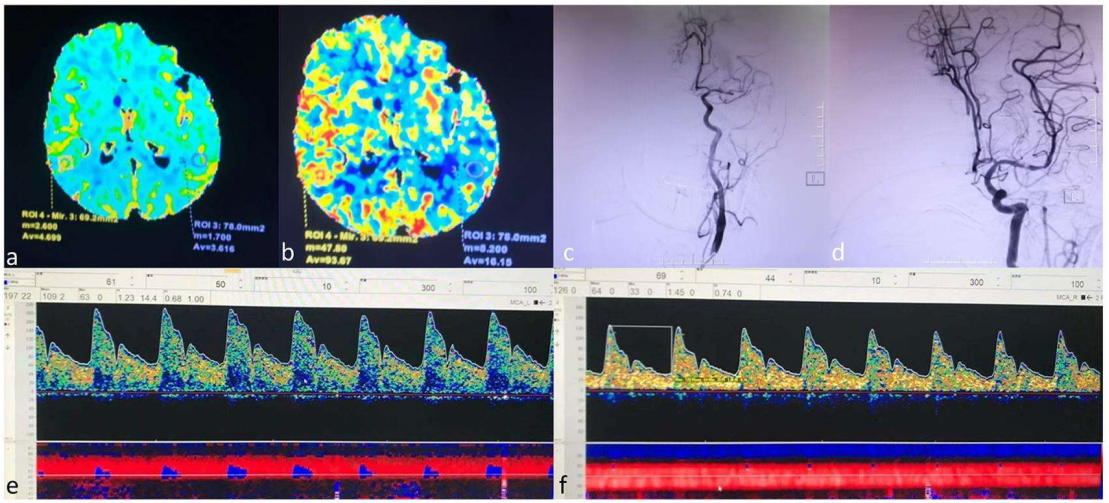
Outcomes	NBM group (n=65)	TBM group (n=65)	Measure of Effect	adjusted OR (95%CI)	p
mRS (0–2)–no.(%)	13 (20.0%)	25 (38.5%)	odds ratio	3.34 (1.36, 8.22)	0.01
mRS (0–3)–no.(%)	22 (33.9%)	37 (56.9%)	odds ratio	3.22 (1.47, 7.05)	0.003
mRS distribution–(ordinal; median, IQR)	5 (3, 6)	3 (1, 5)	common odds ratio	0.37 (0.20, 0.72)	0.003
Death–no.(%)	26 (40.0%)	15 (23.1%)	odds ratio	0.38 (0.17, 0.85)	0.02
Symptomatic ICH–no.(%)	13 (20.0%)	7 (10.8%)	odds ratio	0.43 (0.15, 1.22)	0.11
any ICH–no.(%)	16 (24.6%)	10 (15.4%)	odds ratio	0.53 (0.22, 1.30)	0.17



Methods: Prospective study of 232 patients, non randomized to to TCD BP pressure vs normal BP management.

Bilateral MCA monitoring x 24 hours
Automatic notification when:

- PSV >118 cm/s or >125% of contralateral MCA →**<u>Lower BP</u>** (Urapidil, then diltiazem)
- PSV <78 cm/s → **<u>BP augmentation</u>** (IVF and dopamine or Epi if needed).



Tao C, Xu P, Yao Y, Zhu Y, Li R, Li J, Luo W and Hu W (2021) A Prospective Study to Investigate Controlling Blood Pressure Under Transcranial Doppler After Endovascular Treatment in Patients With Occlusion of Anterior Circulation. Front. Neurol. 12:735758. doi: 10.3389/fneur.2021.735758

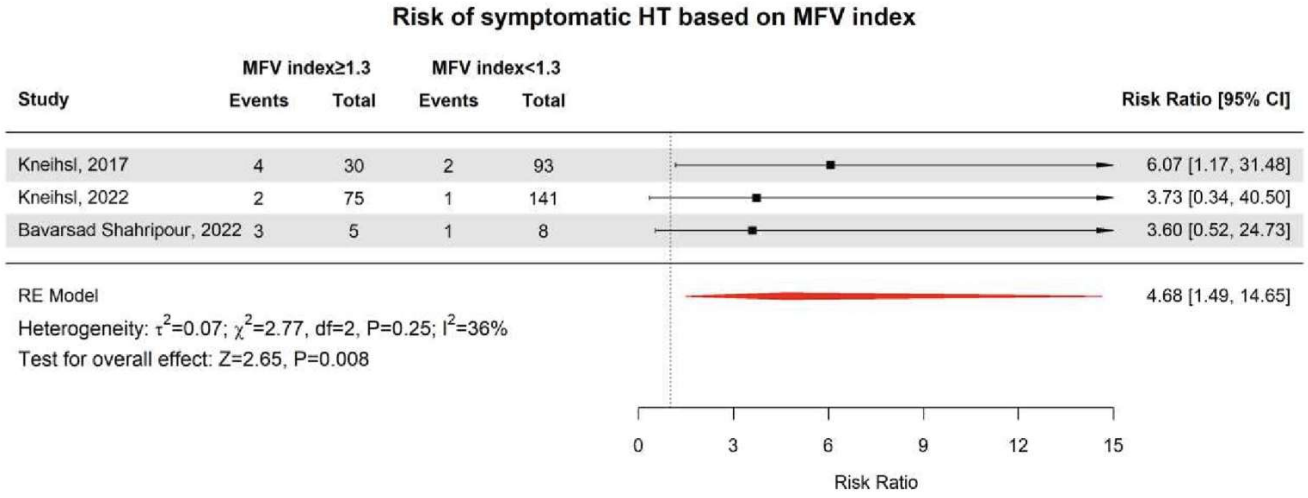
Transcranial doppler (TCD) in predicting outcomes following successful mechanical thrombectomy of large vessel occlusions in anterior circulation: a systematic review and meta-analysis

Seyed Behnam Jazayeri [1,2] Behnam Sabayan,[3,4] Yasaman Pirahanchi,[5] Vikas Ravi,[5] Julián Carrión-Penagos,[5] Jeffrey Bowers,[5] Royya Modir,[5] Kunal Agrawal,[5] Thomas Hemmen,[5] Brett C Meyer,[5] Dawn Meyer,[5] Reza Bavarsad Shahripour[5]

11 studies totaling 1432 patients
- TICI 2b or higher
- Anterior circulation
- TCD 12-24 hours after EVT

- **MFV INDEX** = MFV (affected side)/MFV (unaffected side)

A MFV index >1.3 predicts → Symptomatic ICH and poor outcome.

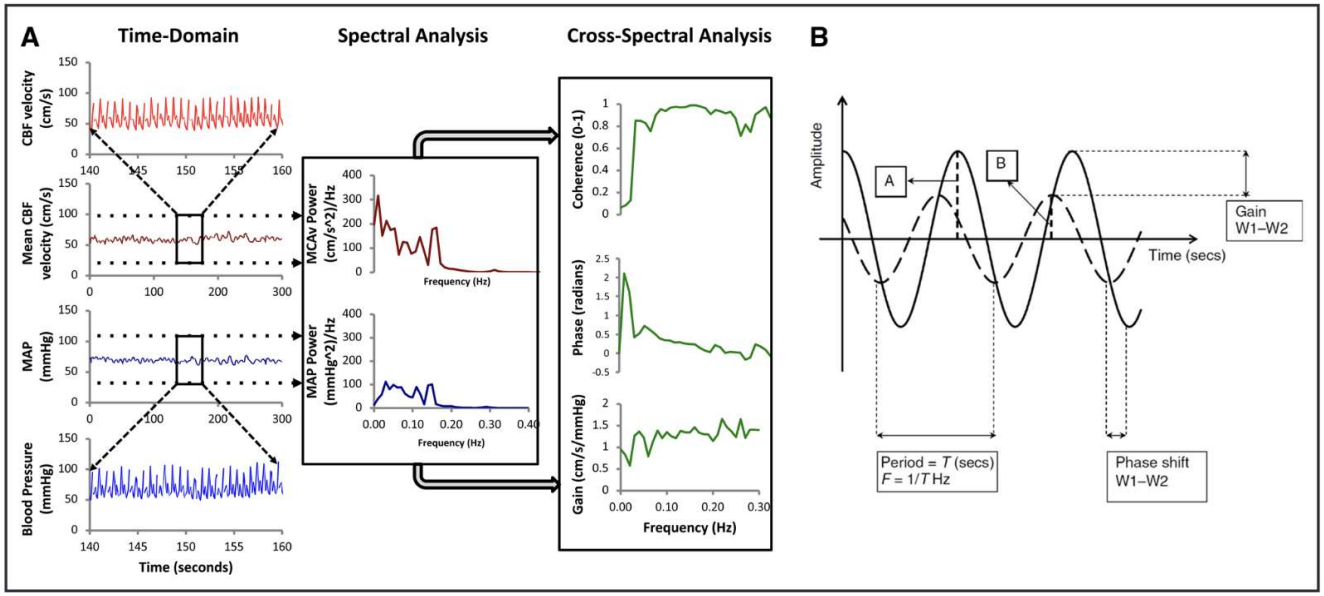


Jazayeri SB, et al. J NeuroIntervent Surg 2025;17:1325–1332. doi:10.1136/jnis-2024-022457

Individual Patient Data Meta-Analysis of Dynamic Cerebral Autoregulation and Functional Outcome After Ischemic Stroke

- Cerebral autoregulation →Maintains perfusion during insults.
- Impaired dCA →Worse outcome after stroke.
- Assessment of dCA is a non-invasive biomarker for prognostication

- Bottomline – dCA metrics are prognostic of outcome at 3 months.



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Conclusion and Thank you

- Other areas
  - Detection of right to left shunt
  - Sickle Cell
  - Cerebral Circulatory Arrest