

Pre-and Post Procedure Non-Invasive Evaluation of the Patient with Carotid Disease

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TRANSCATHETER CARDIOVASCULAR THERAPEUTICS

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Options for Non-Invasive Evaluation Prior to Carotid Revascularization

- Physical Examination
- Carotid Duplex Ultrasonography
- Magnetic Resonance Arteriography
- Computerized Tomographic Arteriography

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- **Physical Examination**
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Finding of a Cervical Bruit does ***NOT*** Define Presence or Severity of Extracranial Carotid Artery Stenosis

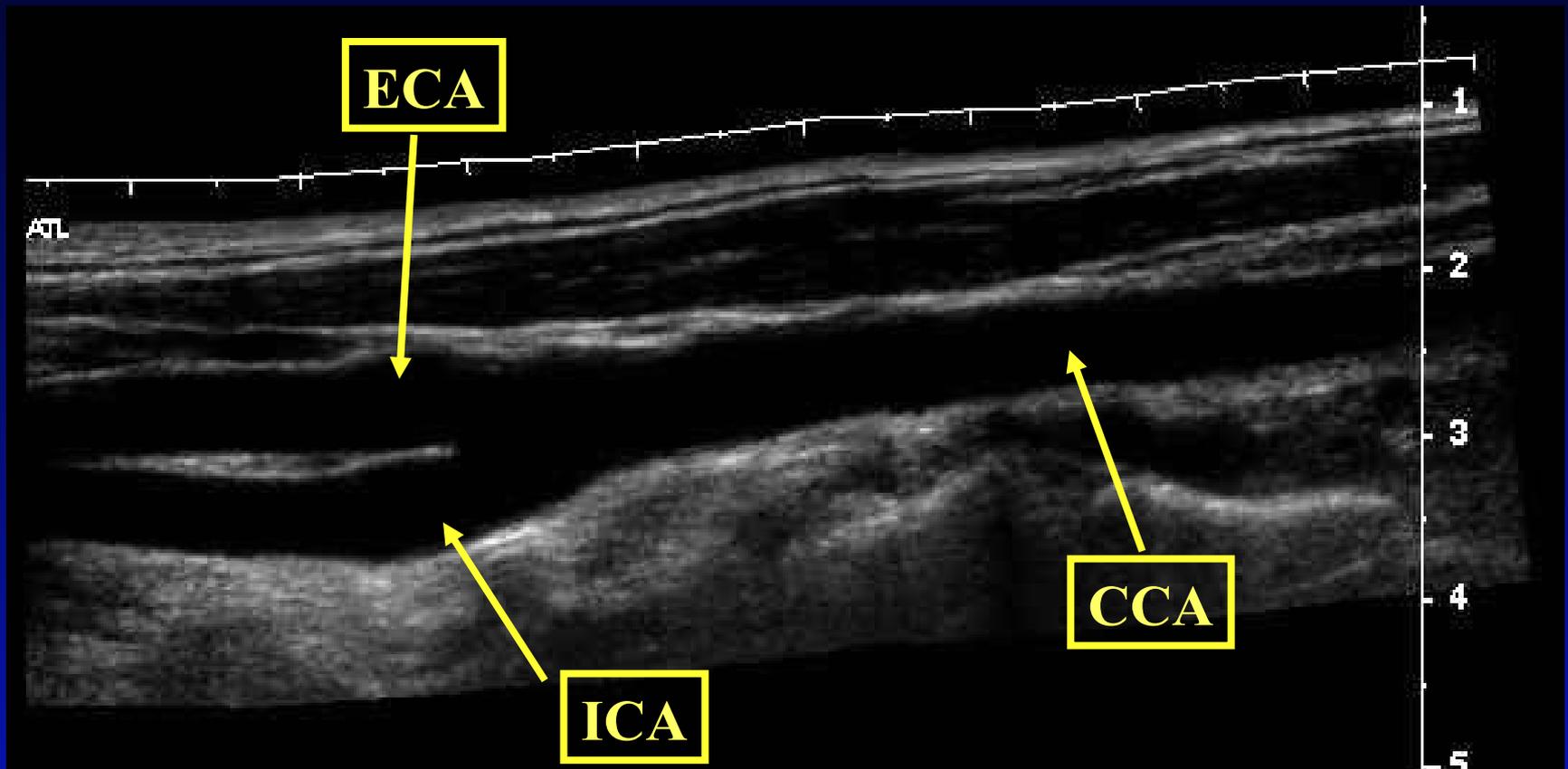
Options for Non-Invasive Evaluation Prior to Carotid Revascularization

- Physical Examination
- **Carotid Duplex Ultrasonography**
- Magnetic Resonance Arteriography
- Computerized Tomographic Arteriography

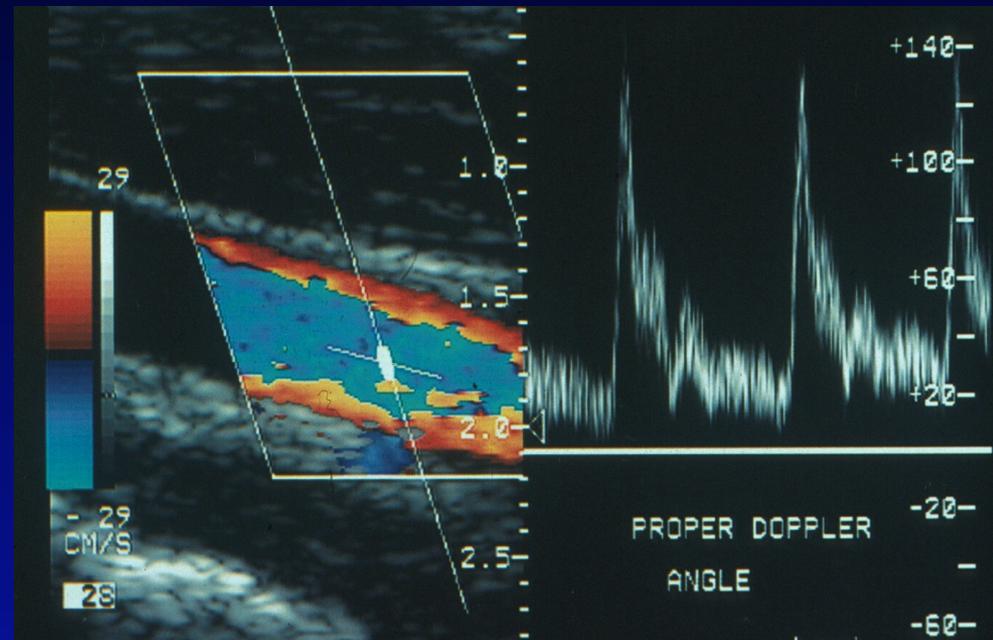
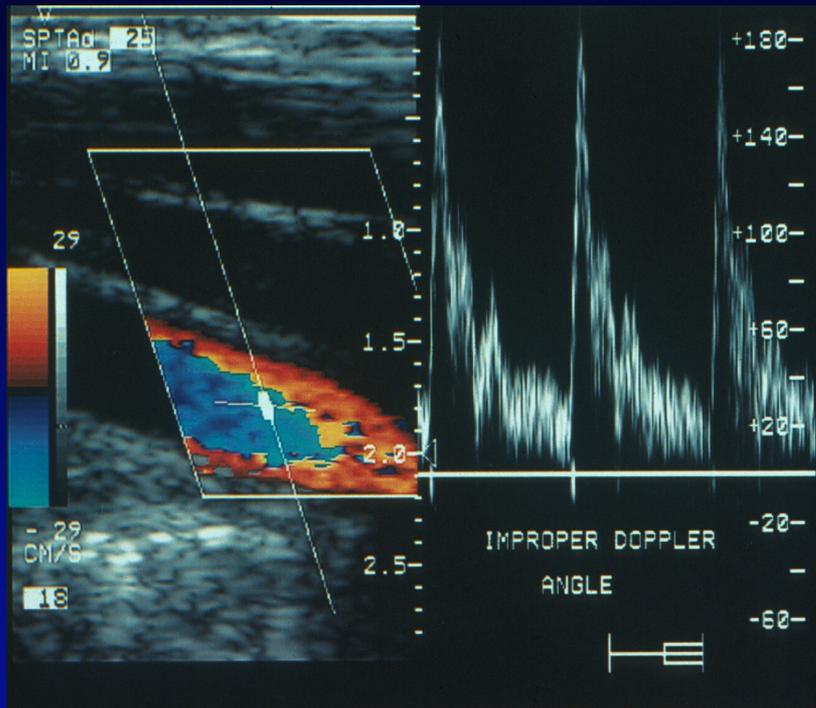
Carotid Duplex Ultrasonography

- Highly accurate and reliable test
- **Advantages**
 - Direct visualization of the extracranial carotid arteries
 - Accurate determination of degrees of stenosis
 - Assess presence and morphology of plaque
 - Useful tool to evaluate revascularization procedures
- DUS can determine anatomic high risk scenarios
 - High bifurcation lesion
 - Ostial CCA stenosis
 - Contralateral Occlusion
- DUS can determine cases suboptimal for CAS
 - Tortuosity
 - Thrombus
 - Dense calcification

Gray Scale Carotid Duplex Scan

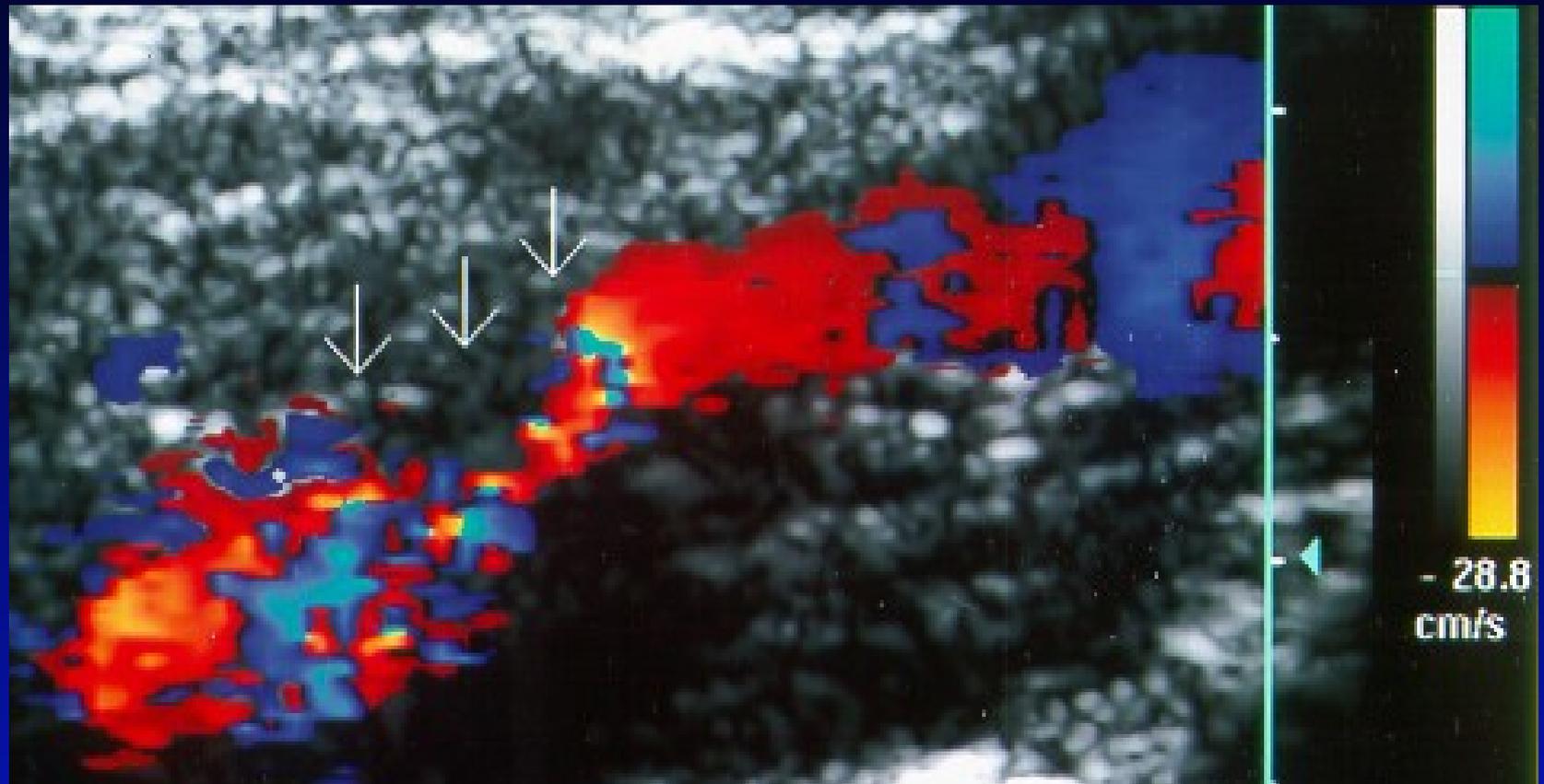


The Importance of a Correct Doppler Angle

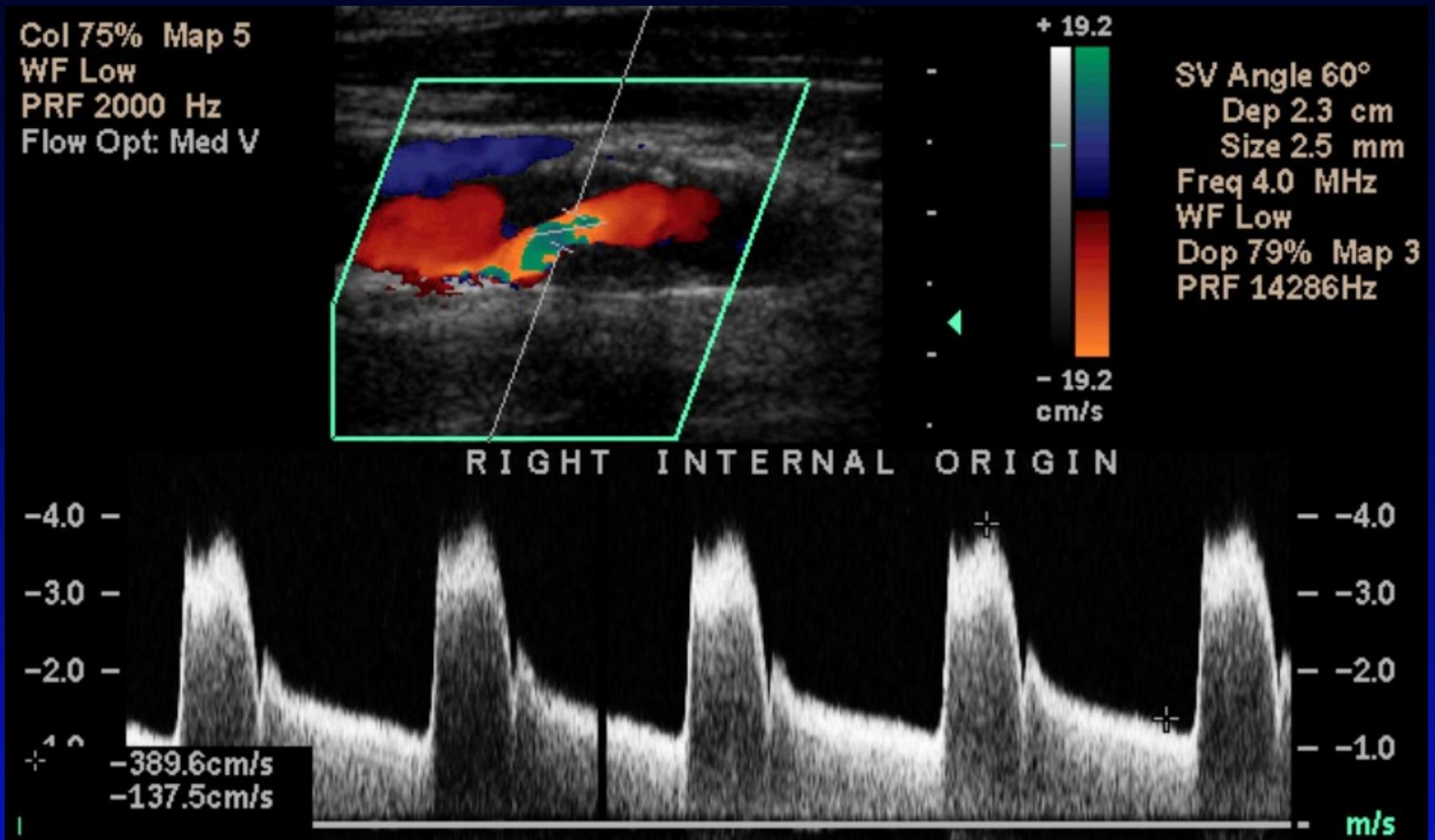


The Angle should never exceed 60°

Carotid Duplex Ultrasonography



80-99% Internal Carotid Artery Stenosis



Modern Criteria for Duplex Ultrasound Determination of ICA Stenosis

	Velocity Criteria, cm/sec	Spectral Broadening
0-19%	≤ 105	No
20-39%	≤ 105	Yes
40-59%	$> 105, \leq 150$	Yes
60-79%	$> 150, \leq 220$	Yes
80-99%	> 220 AND End Diastolic Velocity ≥ 135	Yes
Occluded	No Doppler Signal, Pre-Occlusive Thump	'High Resistant' CCA signal

SRU Consensus Panel Criteria for Grading ICA Stenosis

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

Degree of Stenosis (%)	Primary Parameters		Additional Parameters	
	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

CAVATAS DUS Criteria

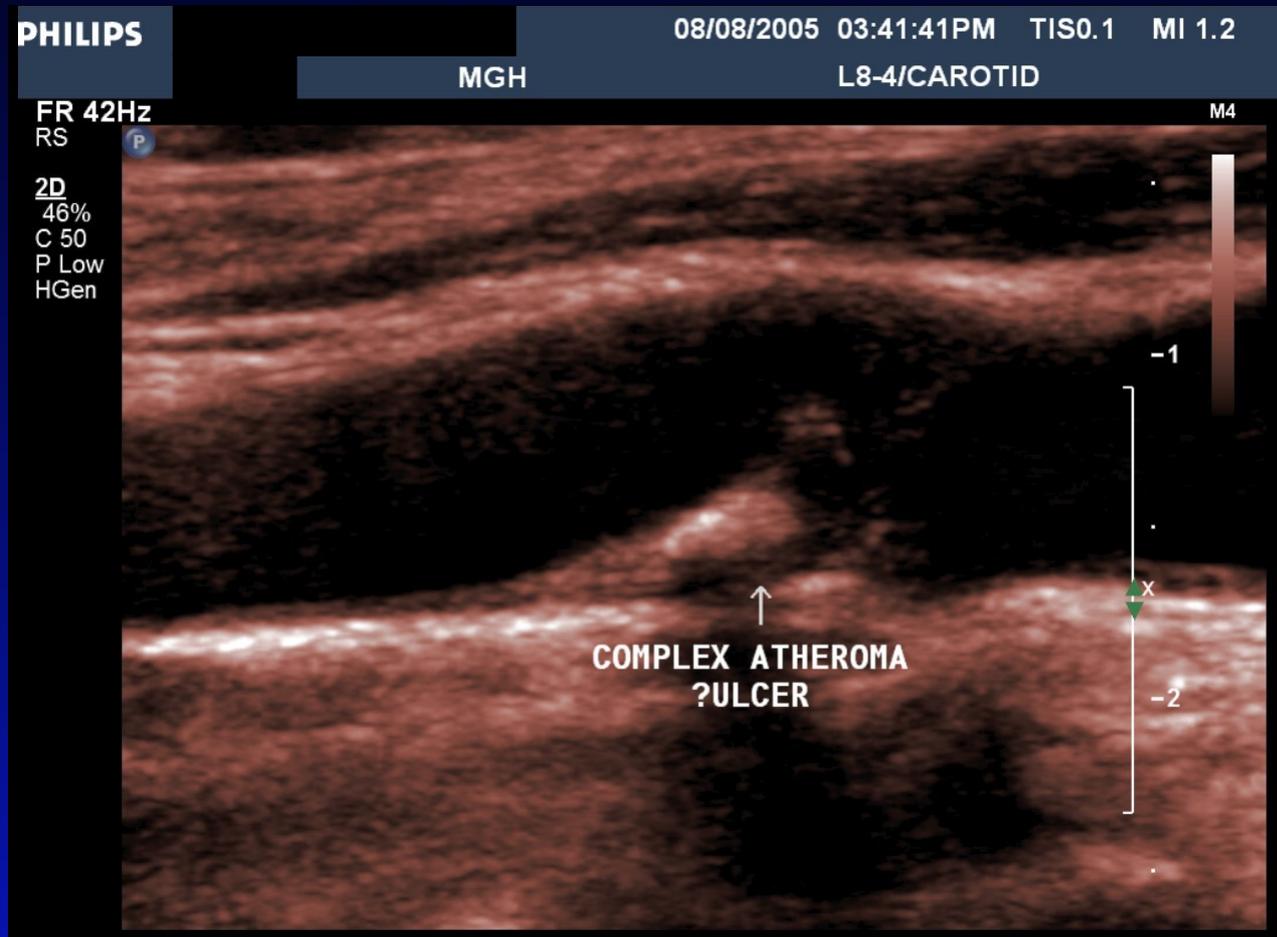
Stenosis (%)	PSV ICA (m/s)	EDV ICA (m/s)	PSV ICA/PSV CCA
0–29	<1.0	<0.4	<3.2
30–49	1.1–1.3	<0.4	<3.2
50–59	>1.3	<0.4	<3.2
60–69	>1.3	0.4–1.1	3.2–<4.0
70–79	>2.1	1.2–1.4	≥4.0
80–95	>2.1	>1.4	≥4.0
96–99	String Flow	String Flow	String Flow
100	Occluded	Occluded	Occluded

Stroke 2005;36:281-6

Pitfalls of Carotid Duplex Imaging

- Misidentification of a pulsatile vein for the internal carotid artery
- Misidentification of the external carotid as the internal carotid artery
 - i.e. External carotid artery with significant stenosis
- Tortuous vessels
- Failure to survey the distal internal carotid artery
- Failure to interrogate the common carotid or innominate arteries
- Near total occlusion (“string sign”)
- Calcification
- Distal ICA or ostial CCA stenosis

Can Carotid Duplex Ultrasonography Detect Vulnerable Plaque?

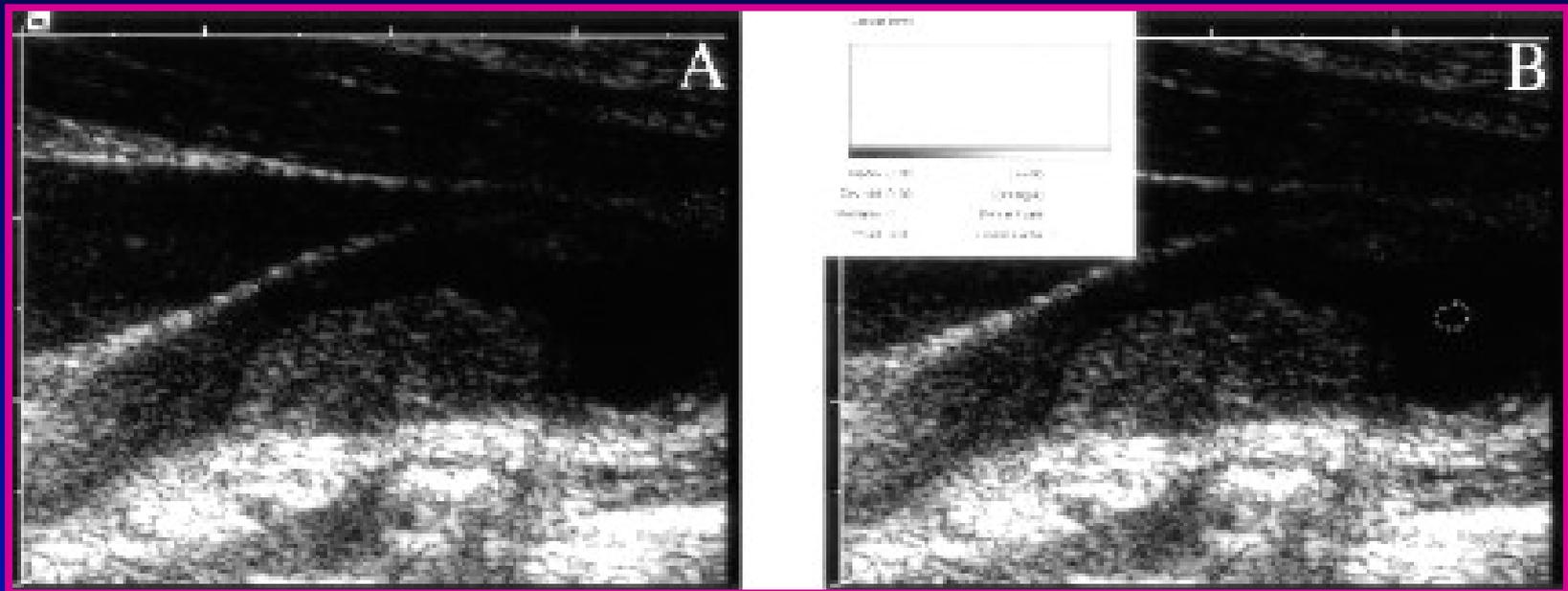


Prediction of Stroke with CAS— The ICAROS Trial

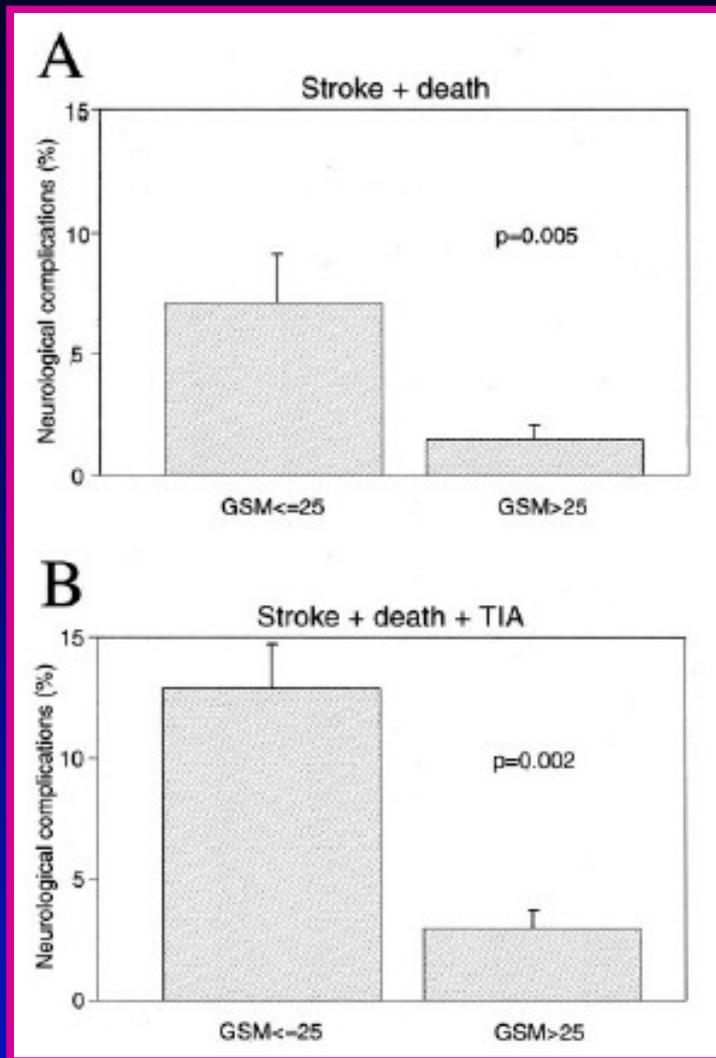
- 496 CAS procedures worldwide evaluated pre-intervention with duplex-US derived Gray Scale Median (GSM) scores
- 415 cases actually underwent CAS
 - 219 cases with embolic protection devices
- CAS Complications
 - 13 TIAs
 - 9 Minor CVAs
 - 6 Major CVAs
 - 0 Deaths

Prediction of Stroke with CAS— The ICAROS Trial

Gray Scale Median: Based on notion that echolucent plaques have higher embologenic potential than echodense plaques



Prediction of Stroke with CAS— The ICAROS Trial

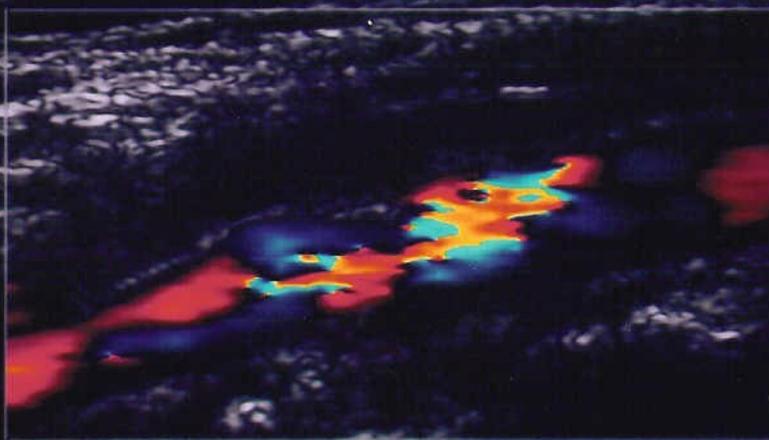


Prediction of Stroke with CAS— The ICAROS Trial

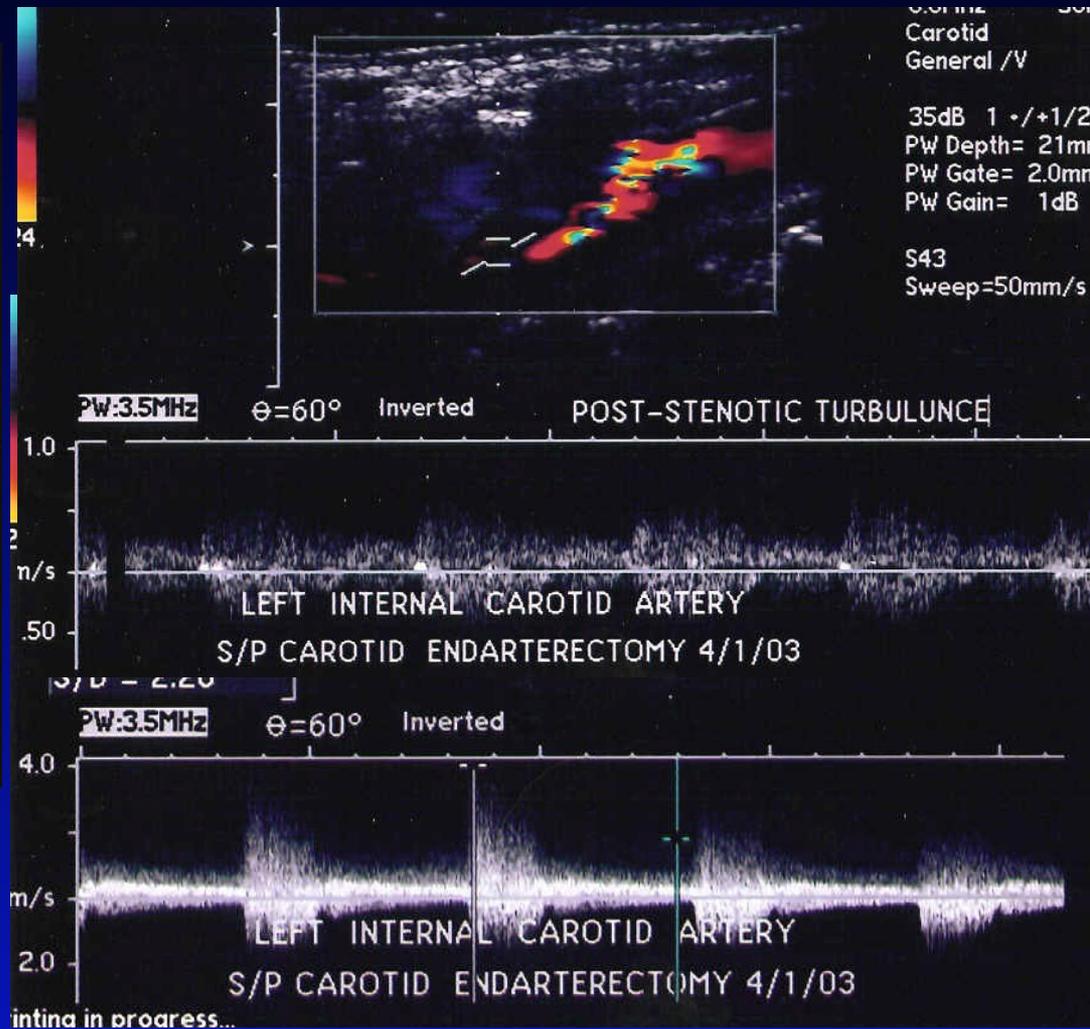
Multiple Logistic Regression Analysis Odds Ratio of Stroke

	OR	P	95% CI
GSM			
≤ 25 vs > 25	7.11	0.002	2.06–24.57
Stenosis, %			
≥ 85 vs < 85	5.76	0.010	1.51–21.91
Symptomatology			
Symptomatic vs asymptomatic	2.92	0.061	0.95–8.93
Brain CT			
Positive vs negative	2.54	0.099	0.84–7.47

Carotid Duplex Ultrasonography Post-CEA



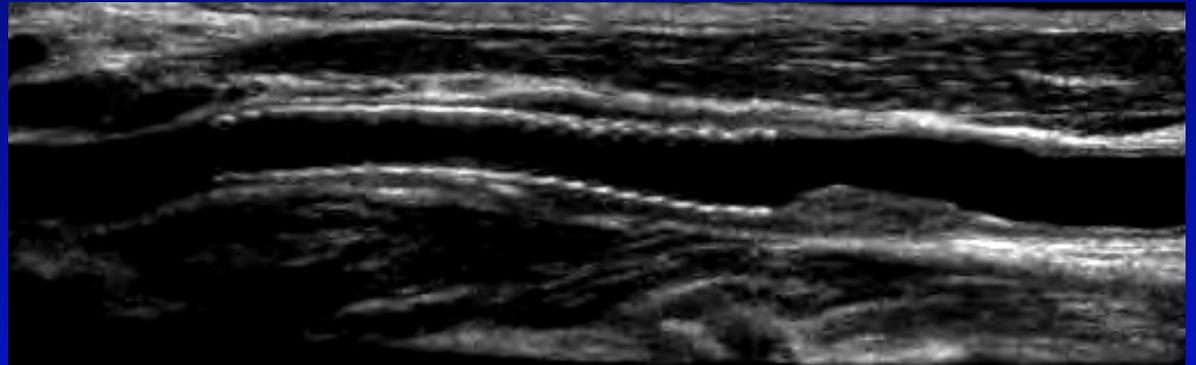
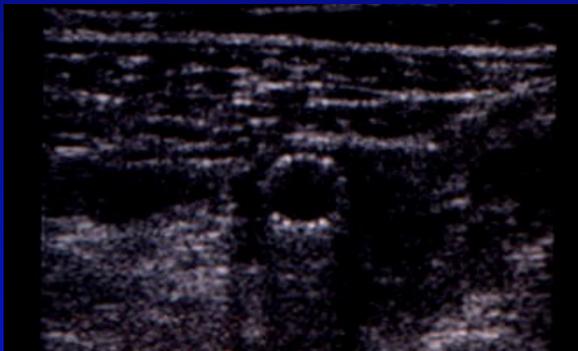
LEFT INTERNAL CAROTID ARTERY
S/P CAROTID ENDARTERECTOMY 4/1/03



Carotid Duplex Sonography of Endovascular Stents

B-mode image: More important than in Native DUS

- Evaluate stent from 2 views in gray scale
- Proximal and distal ends: apposition to wall
- Stent integrity
- Confirm abnormal findings from 2 views
- Include proximal and distal native vessel



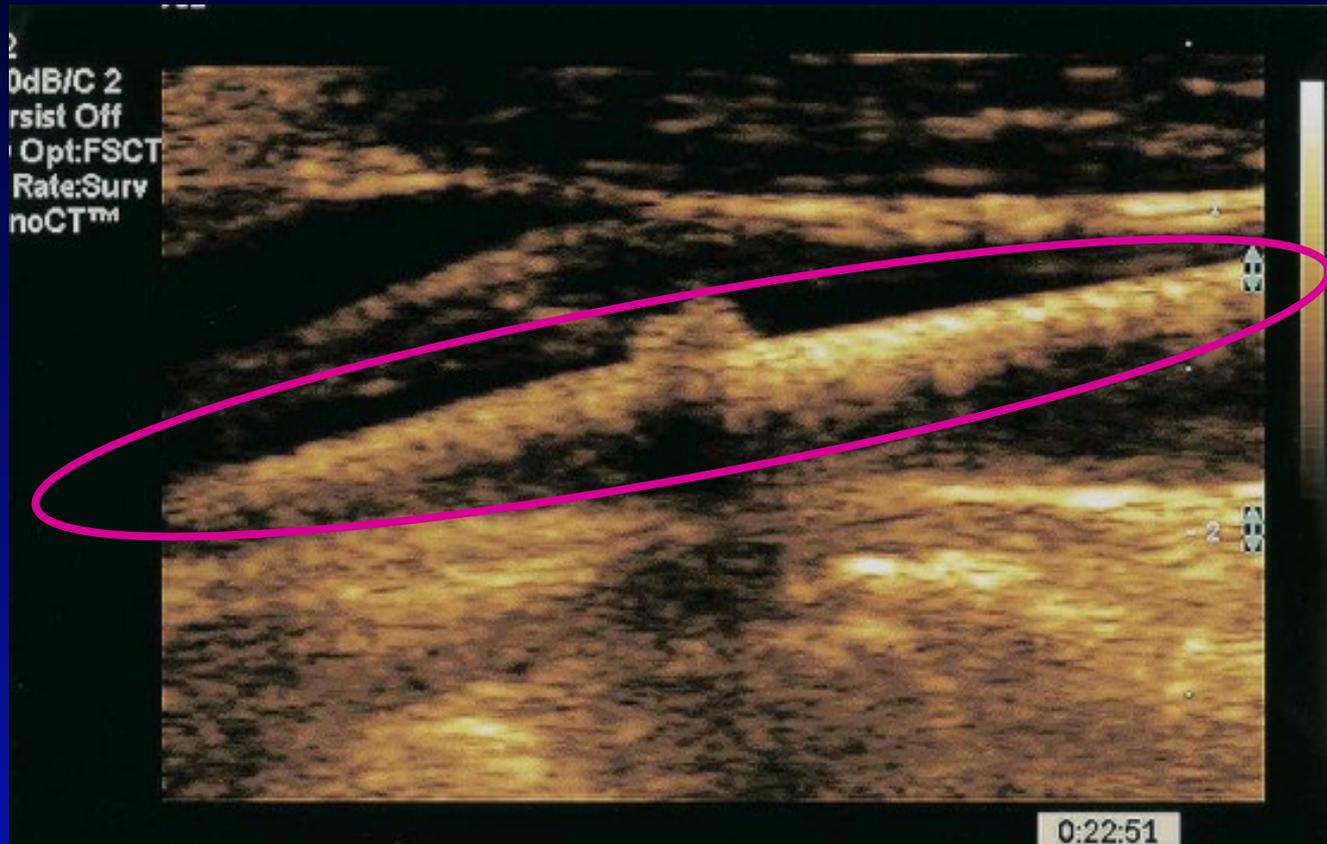
Post-Stent Gray Scale B Mode is Critical



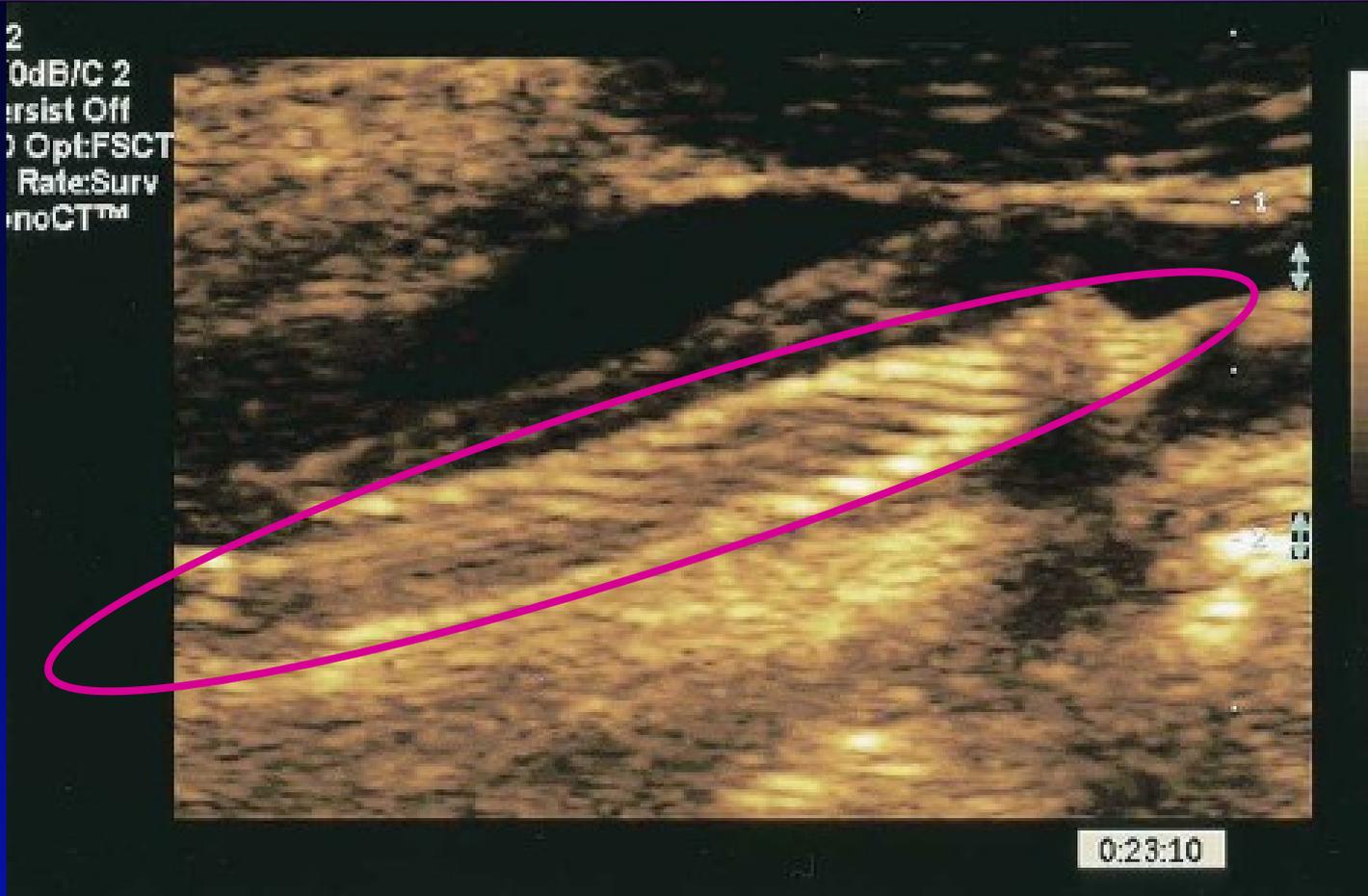
24 Hours Post-ICA Stent



Duplex Assisted Carotid Artery Stenting



Duplex Assisted Carotid Artery Stenting



Duplex Assisted Carotid Artery Stenting



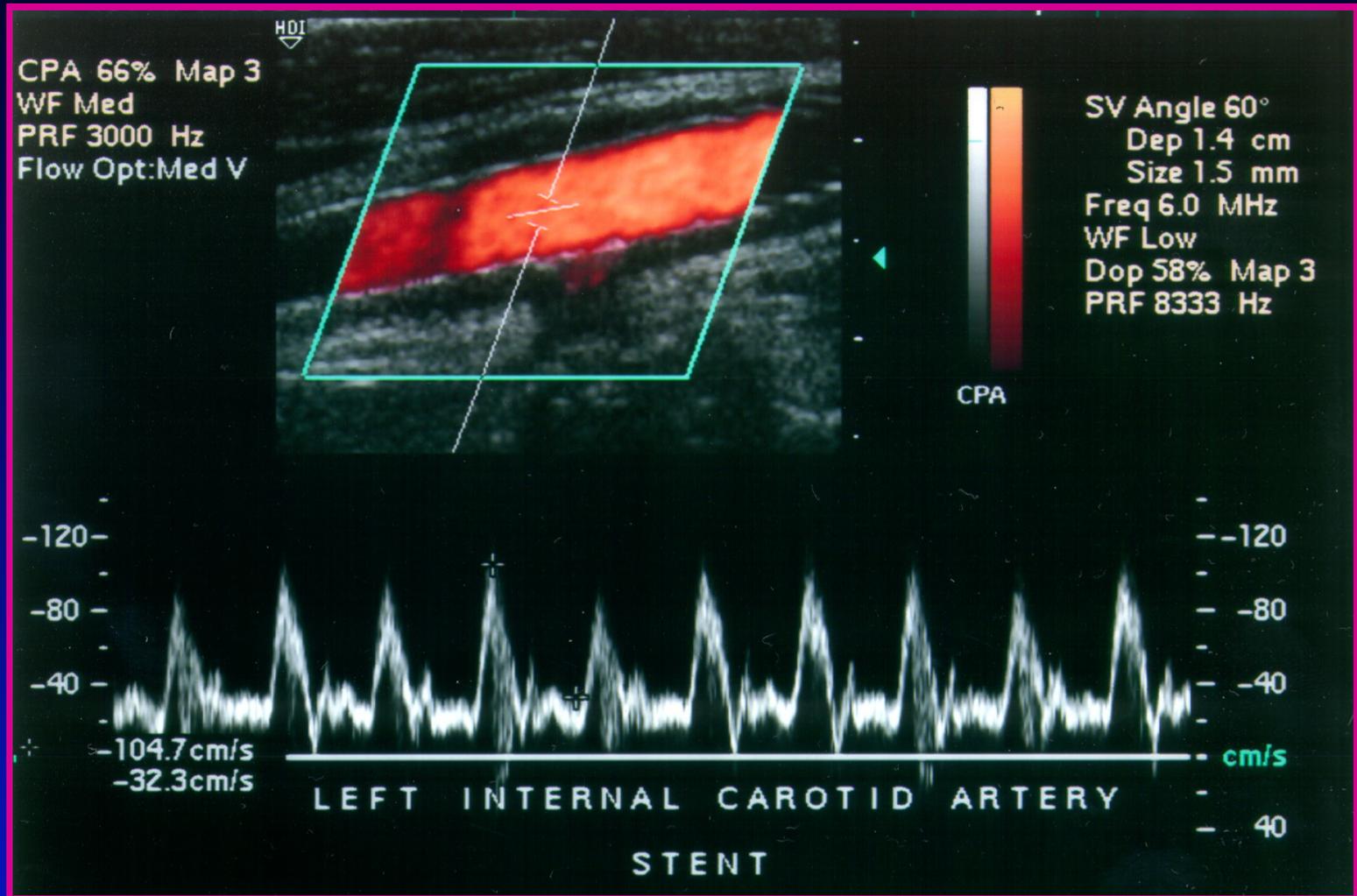
Selection of Patients for Carotid Stenting Using DUS Findings

- Retrospective study of 139 patients with carotid DUS available hospital records
- Plaque Characteristics on DUS
 - 58% had irregular surfaces
 - 53% with heterogeneous findings
- Combination of irregular, heterogeneous plaques increased risk of ipsilateral neurologic events ($p < 0.0001$)
- Implications for carotid stenting?

Problems with Carotid Duplex Ultrasonography in Stented Carotid Arteries

- No well performed, prospective trials validating carotid duplex US in carotid stents
- Early experience suggests that peak systolic velocities (PSV) after carotid stenting are elevated when compared to non-stented arteries
- Plaque shadowing
- Stent deployment issues

Carotid Duplex Ultrasonography-- Carotid Stent Imaging

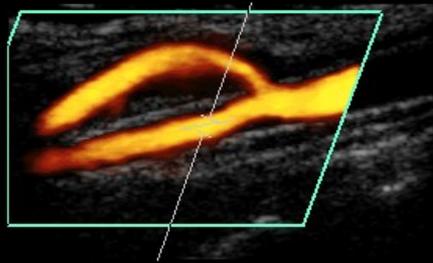


DUS Follow-Up of Stented Carotid Arteries

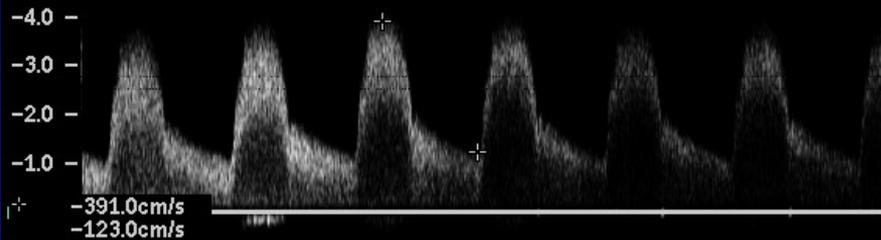
- 114 patients
- Angiography immediately after carotid stent deployment
- DUS performed within 1 week of procedure
 - Four Criteria used
 - 1) Peak in-stent SV >125 cm/s
 - 2) ICA/CCA >3.0
 - 3) Peak in-stent SV >170 cm/s
 - 4) ICA/CCA >2.0

Carotid In-Stent Restenosis

CPA 76% Map 4
WF Med
PRF 3000 Hz
Flow Opt: Med V

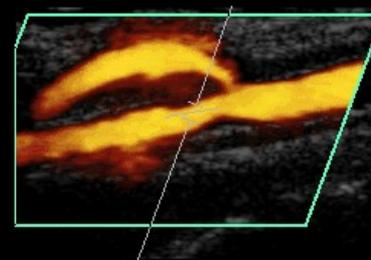


SV Angle 58°
Dep 1.6 cm
Size 1.5 mm
Freq 4.0 MHz
WF Low
Dop 56% Map 3
PRF 16667Hz

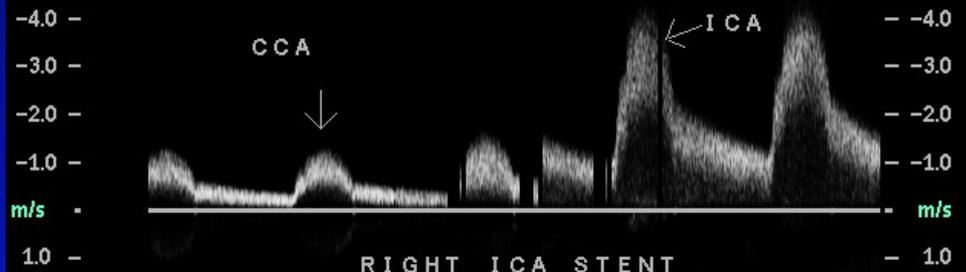


RIGHT ICA STENT

CPA 76% Map 4
WF Med
PRF 3000 Hz
Flow Opt: Med V



SV Angle 58°
Dep 1.5 cm
Size 1.5 mm
Freq 4.0 MHz
WF Low
Dop 56% Map 3
PRF 16667Hz



RIGHT ICA STENT

DUS Follow-Up of Stented Carotid Arteries

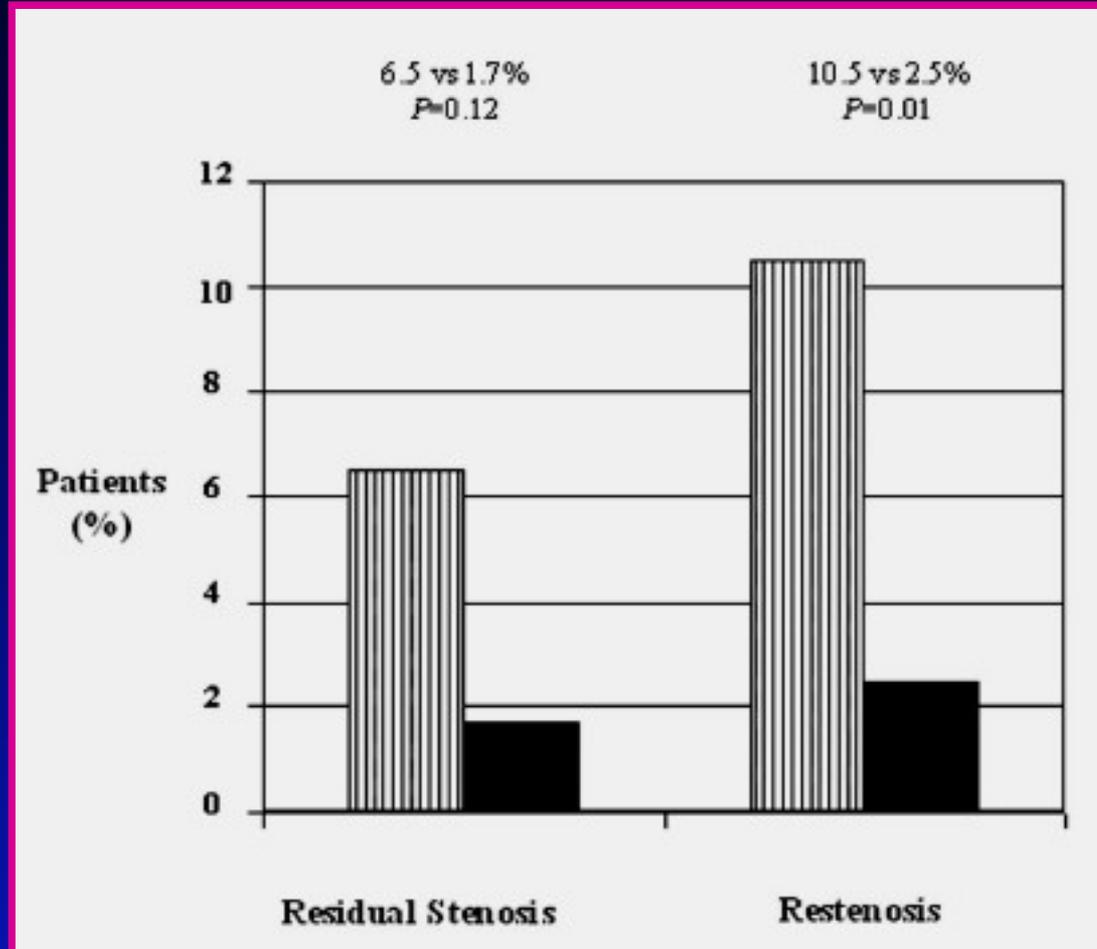
Criteria	Number of Patients
PSV In Stent >125 cm/s	36
ICA/CCA Ratio >3.0	3
PSV In Stent >170 cm/s	8
ICA/CCA Ratio >2.0	14

DUS Follow-Up of Stented Carotid Arteries

- No patient with DUS evidence of stenosis had angio evidence of >50% residual stenosis
- 3/9 with follow-up angio had restenosis
- In each of these 3 patients, all had increase in PSV >80% since post-stent DUS

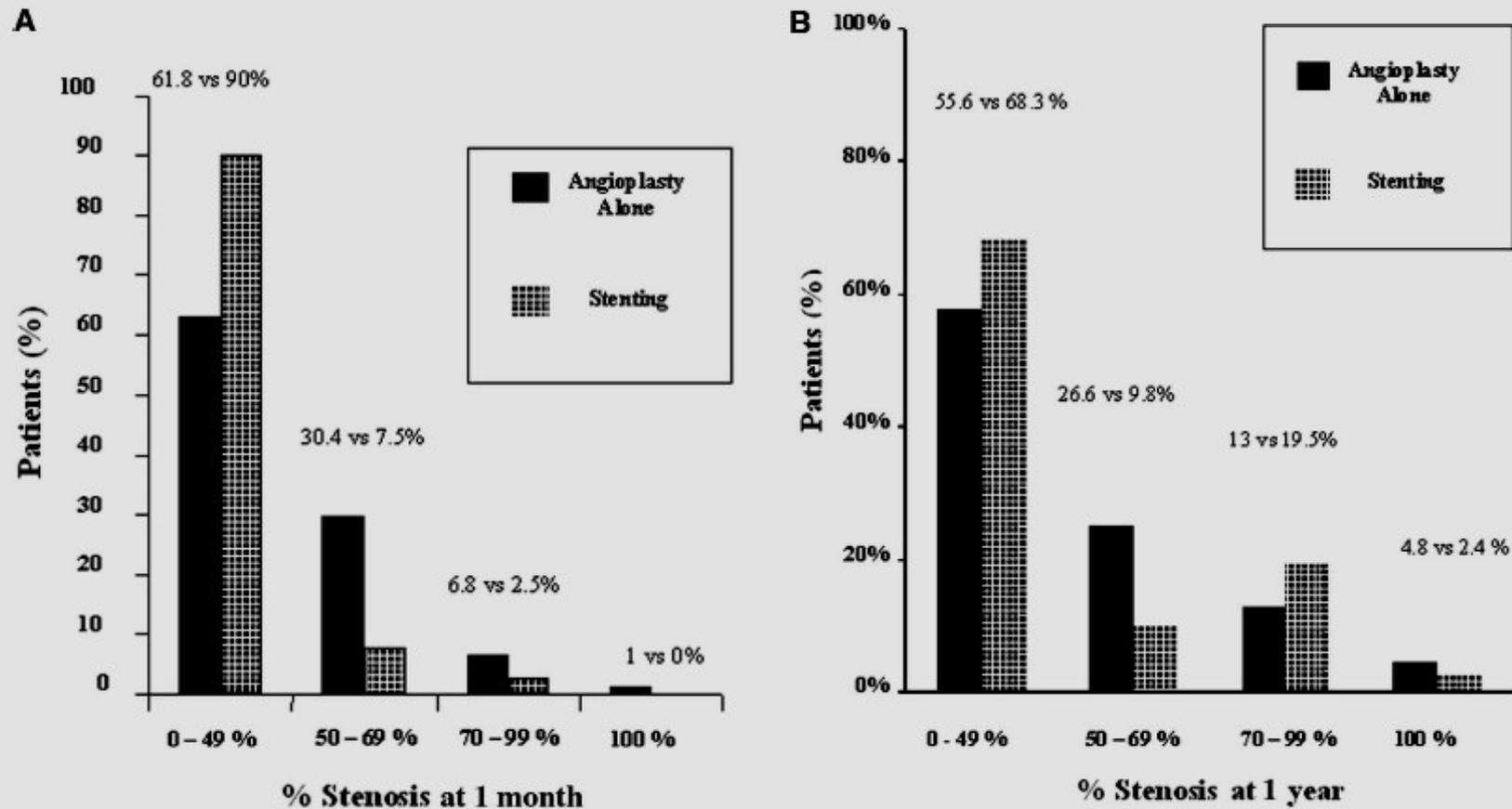
CAVATAS

Restenosis: CEA vs Endo



CAVATAS

Restenosis: PTA vs Stent



CAVATAS

Restenosis: Endo vs Surgery

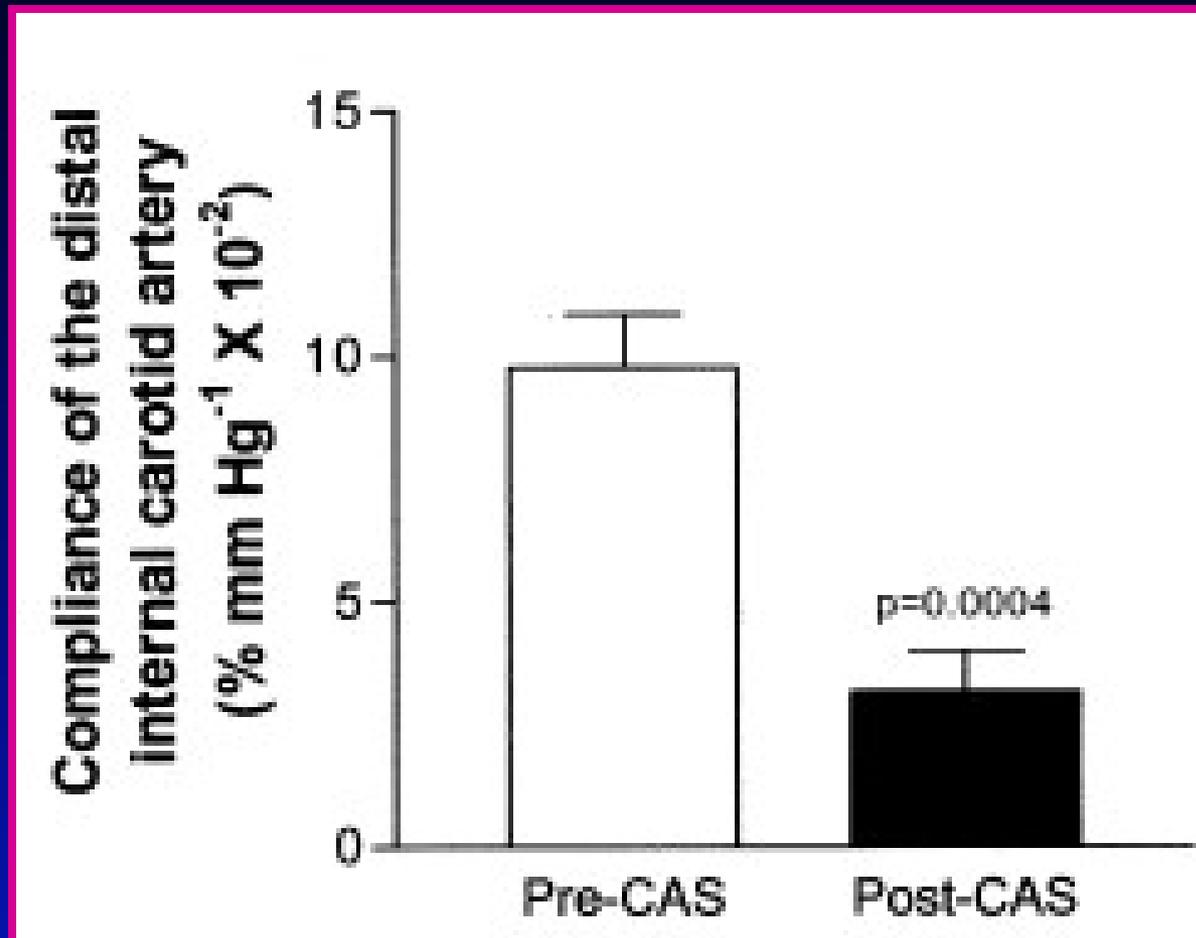
	Stenosis Severity	TIA/AF	RS	NDS	DS	FS	Total
Endovascular patients	<70% (n=141)	7 (5.0)	1 (0.7)	0	0	3 (2.1)	11 (7.8)
	≥70% (n=32)	4 (12.5)	0	1 (3.1)	0	0	5 (15.6)*
Surgery patients	<70% (n=165)	5 (3.0)	0	3 (1.8)	2 (1.2)	0	10 (6.1)
	≥70% (n=9)	0	0	0	0	0	0

*p=0.02

What are the Current Criteria for Carotid Stent Duplex Ultrasonography?

- Peak Systolic Velocity <150 cm/sec
- ICA/CCA PSV Ratio <2.16

Why Are Velocities Higher in the Stented ICA?



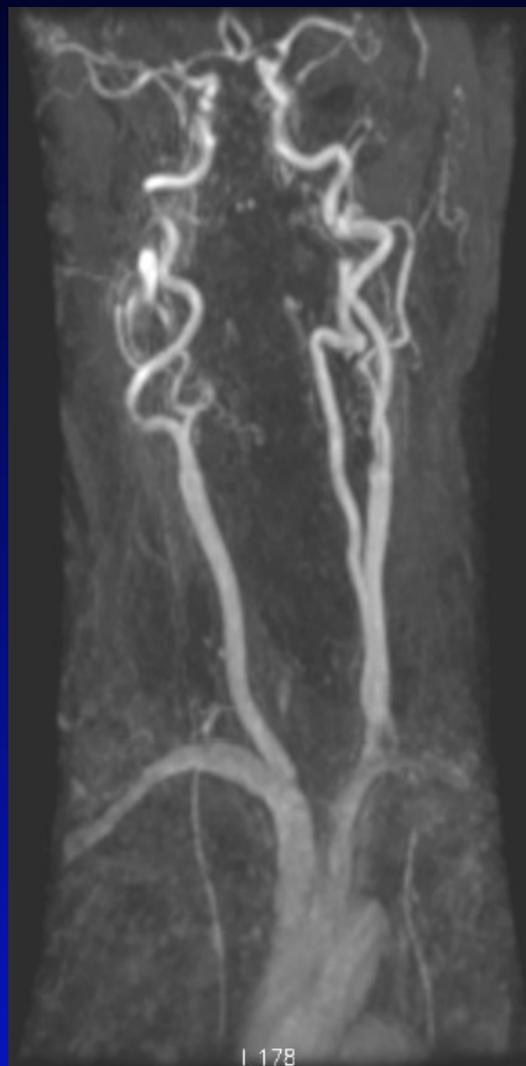
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- **Magnetic Resonance Arteriography**
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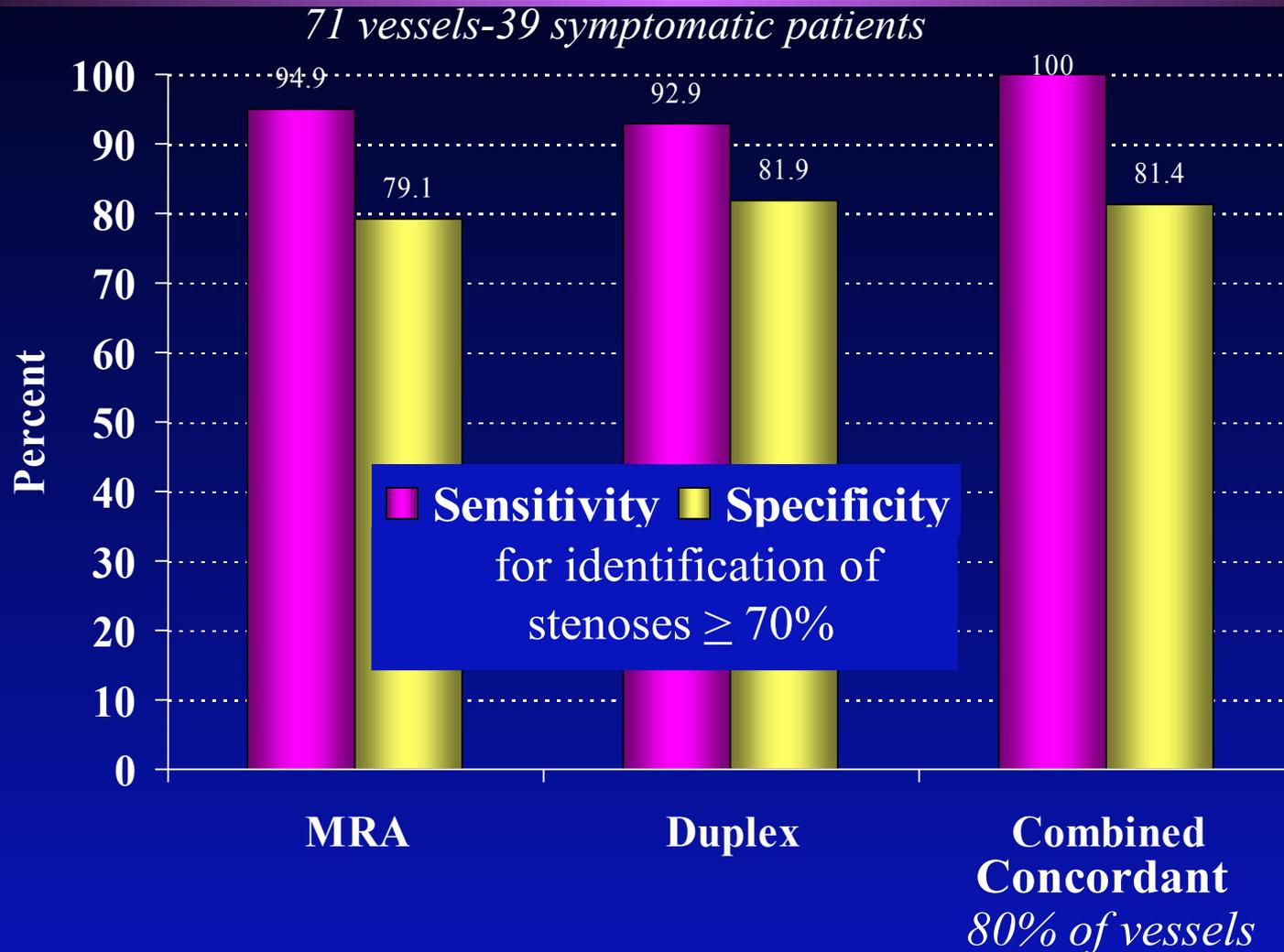
Gd Enhanced MRA

- **No ionizing radiation**
- **Non-invasive (no arterial catheterization)**
- **Non-nephrotoxic contrast**
- **Allergic reactions rare**
- **High accuracy**
- **3D allows multiplanar reformatting**
- **Decreased cost**
- **SUPERIOR IMAGE QUALITY**
- **FAST IMAGING**

Carotid MRA



Preoperative Evaluation of Carotid Artery Stenosis: Comparison of Contrast-MR Angiography and Duplex Ultrasonography with Digital Subtraction Angiography



Carotid Artery Imaging: Duplex US vs. MRA

Nederkoorn et al. Stroke 2003

- **Statistical review of DUS and MRA literature**
- **63 publications (1994-2001) comparison to DSA**

% Stenosis	Pooled Sensitivity, % (95% CI)		Pooled Specificity, % (95% CI)	
	MRA	DUS	MRA	DUS
70-99% vs. < 70%	95 (92-97)	86 (84-89)	90 (86-93)	87 (84-90)

Carotid Artery Imaging: Duplex US vs. MRA

Nederkoorn et al. Stroke 2003

“...MRA has a better discriminatory power compared with DUS in diagnosing 70-99% stenosis and is a sensitive and specific test compared with DSA in the evaluation of carotid artery stenosis.”

So... Which Is Better? DUS vs MRA

	DUS	MRA
Determine >70% Stenosis	✓	✓
Determine 50-69% Stenosis	✓	✓
Plaque Morphology	✓	<i>Not Yet</i>
Assess Revascularization Adequacy: CEA	✓	✓
Assess Revascularization Adequacy: CSSA	✓	■

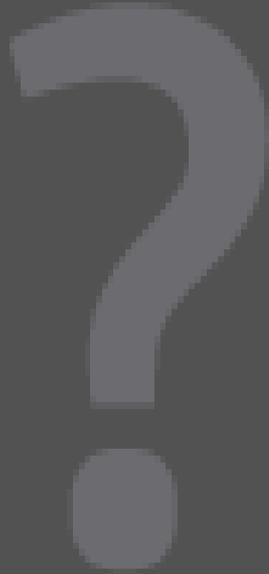
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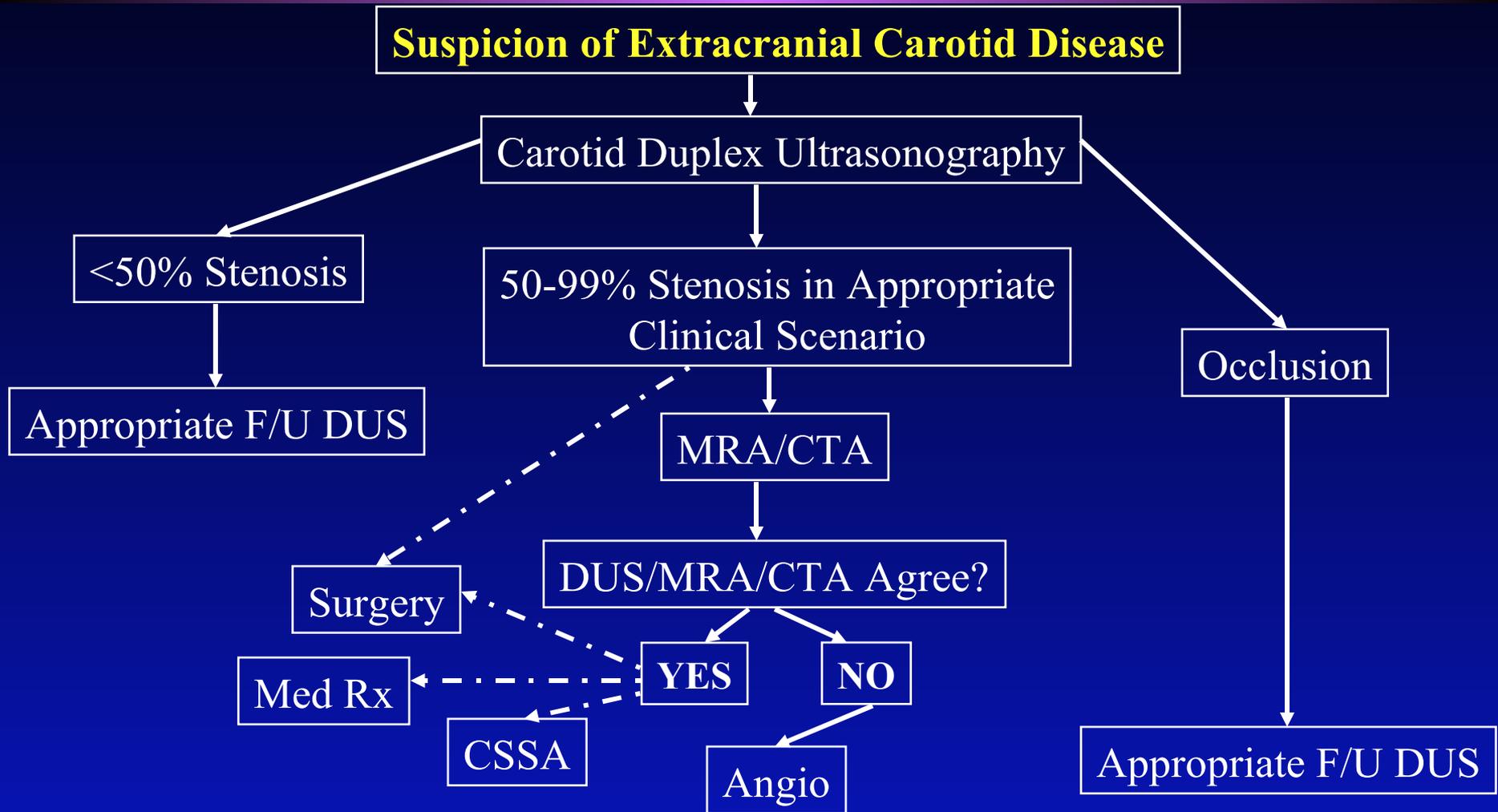
CT Angiography

- New and emerging technology
- Requires intravenous iodinated contrast
- Requires significant radiation exposure
- Allows for three dimensional wide field of view
- Able to detect and characterize calcification

Cerebrovascular CT Angiography



Modern Diagnostic Algorithm for Extracranial Carotid Disease



Who Needs a Carotid Arteriogram?

- Discordance between DUS and MRA/CTA
- Poor quality DUS or MRA in patient considered for revascularization
- DUS suggestive of high grade ICA stenosis and decision to treat with CSSA
- Atypical presentation in symptomatic patients
 - ie FMD, Trauma