Classification of Intracranial Stenosis (actually accepted criteria, vasospasm after SAH, pitfalls

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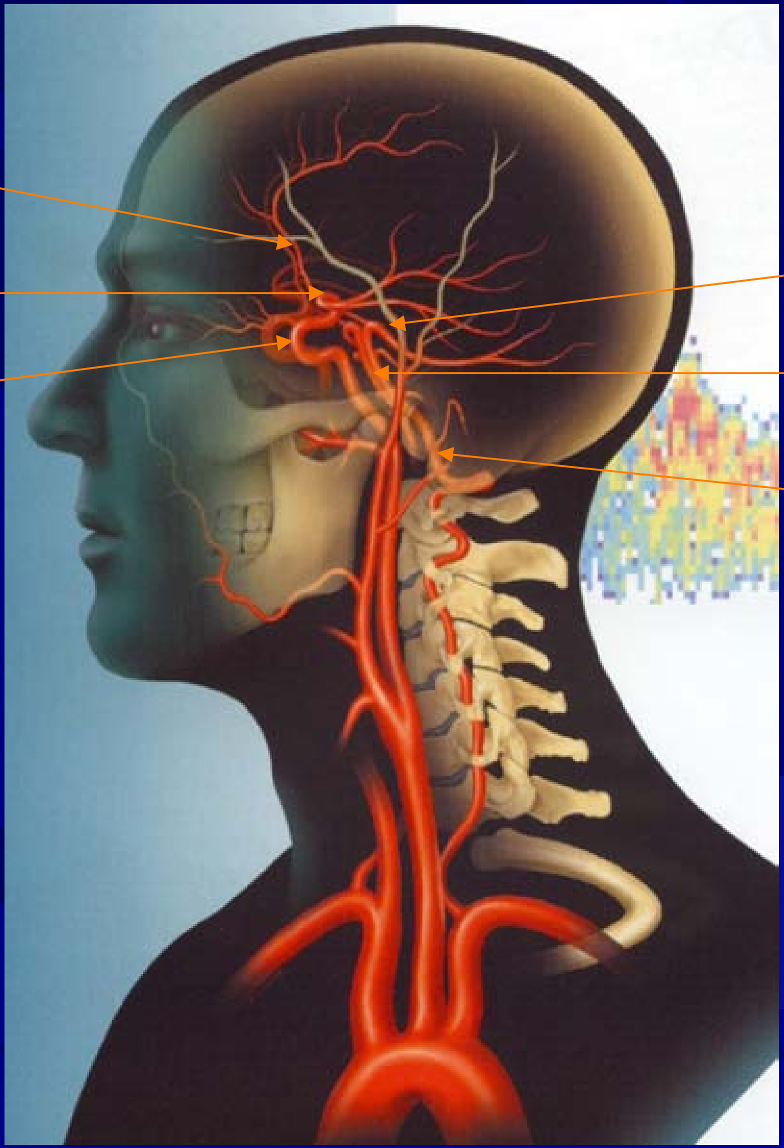
Frequency of ICS among ischemic stroke patients

- Chinese 33-50%
- Thai 47%
- Korean 56%
- Singapore 48%
- Japan 28%
- Caucasians 8%

International Journal of Stroke 2006; 1 (3), 158–159.

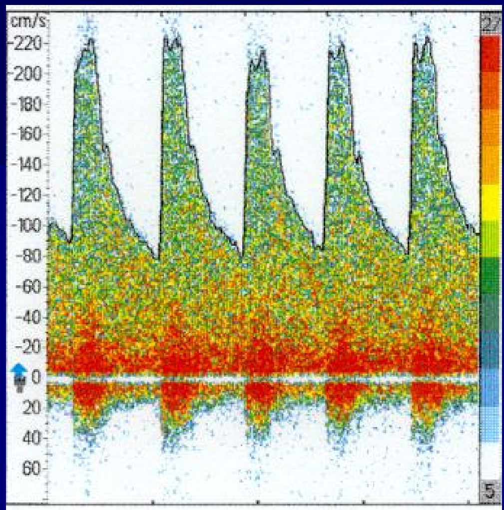
International Journal of Stroke

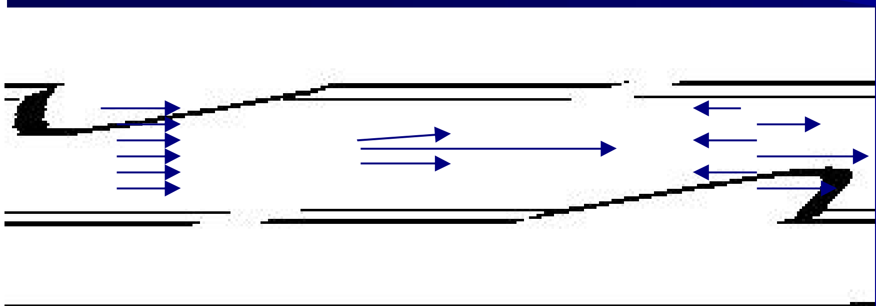

ACA
MCA
Siphon ICA
PCA
BA
VA

Why TCD?

- Portable
- In-expensive
- Repeated examination
- Monitoring
- Best suited for : emergence room, TIA clinic, population screening
- Neurologist's stethoscope

Criteria for diagnosis of intracranial artery stenosis





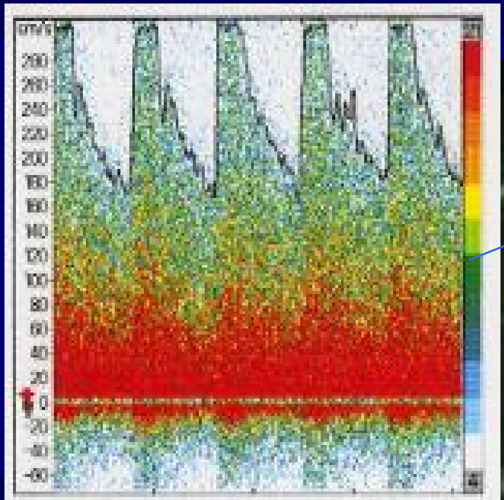
- **Stenosis >50% in lumen reduction.**
- **Circumscribed flow velocity increase within a stenosis. (Vs ≥ 140 cm/sec).**
- **Turbulence appearing in both sides of zero baseline result from flow disturbance distal to stenosis.**
- **Side-to-side differences in velocity**

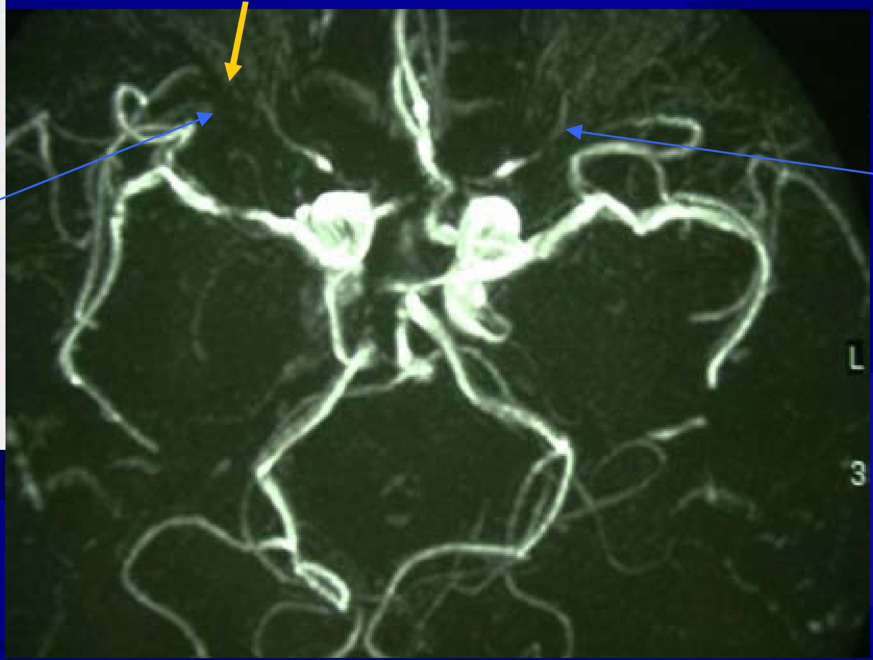
- Decrease FV downstream from a stenotic site.
- Decrease FV proximal and increase PI proximal to the stenotic site.
- Increase FV and/or reverse flow in collateral vessels (like the finding of reverse blood flow in the OA in case of ipsilateral carotid artery occlusion and the finding of increased FV of the first segment of contralateral ACA shunting blood through the anterior communicating artery to the contralateral hemisphere in the same scenario).

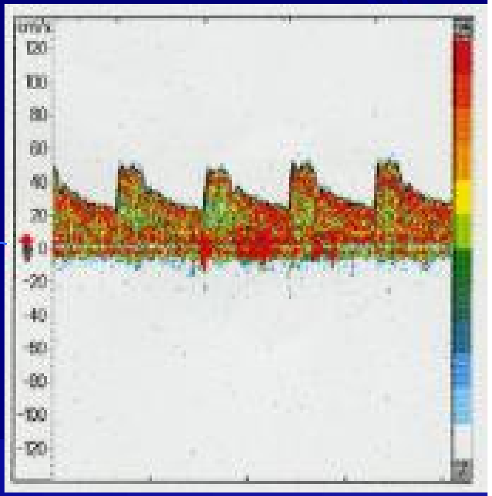
Criteria for diagnosis of intracranial artery occlusion

- No flow signal from an artery
- signals present from other arteries insonated through same window
- signs of collateral flow

Case one





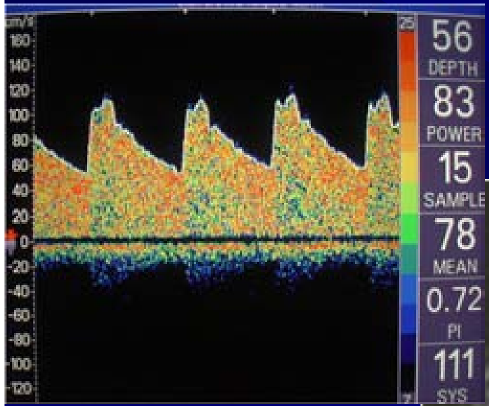


Vs=300cm/sec
Depth 56 mm

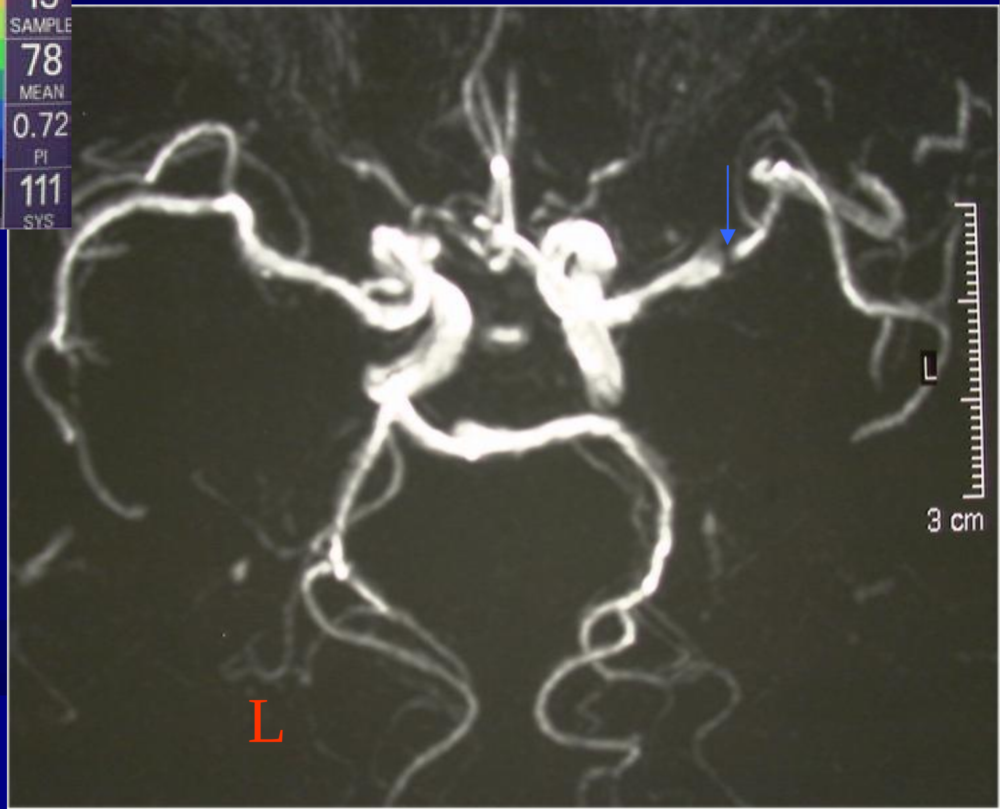
Vs=60cm/sec
Depth 56 mm

MRA-right MCA stenosis

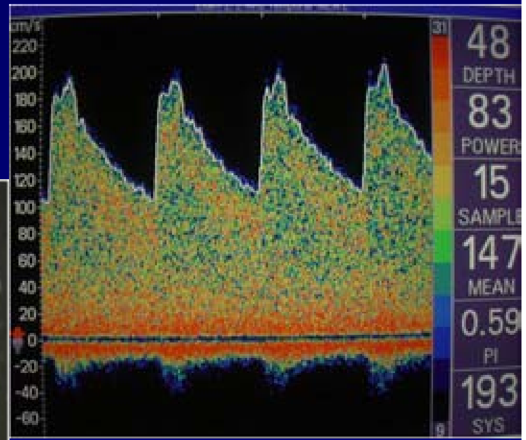
Vs=120 cm/sec



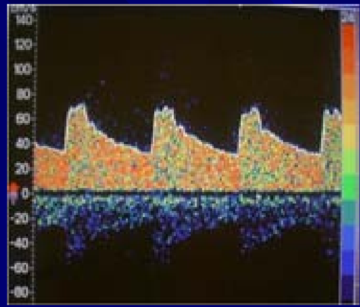
R MCA



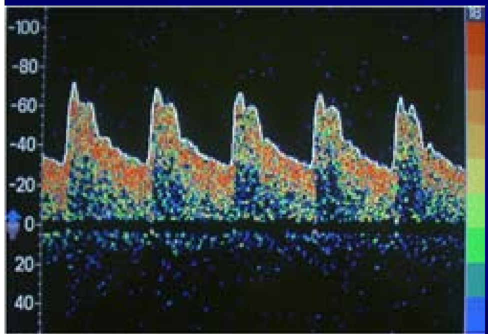
Vs=220 cm/sec



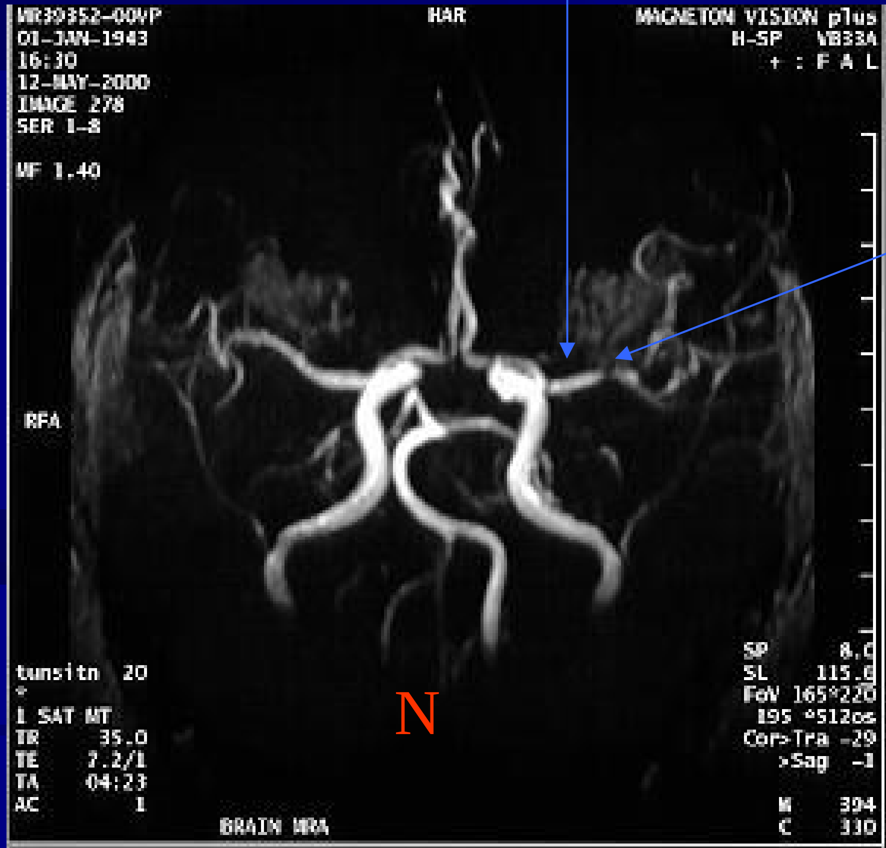
L MCA
Depth 60-40 mm

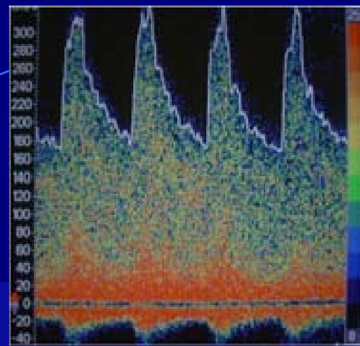


L MCA depth 58mm



R MCA

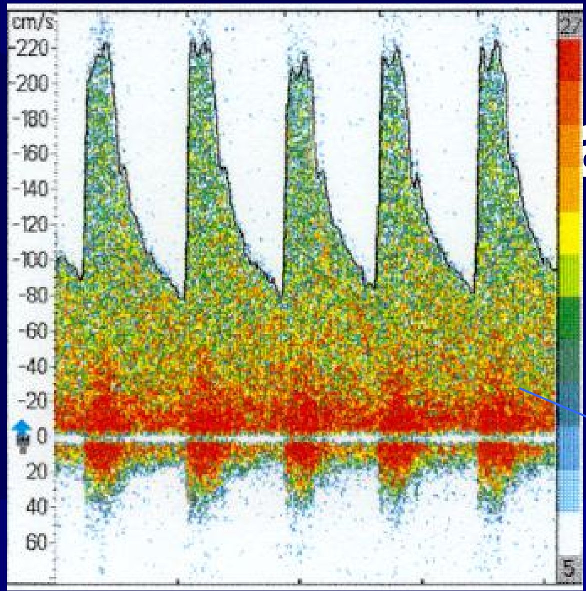




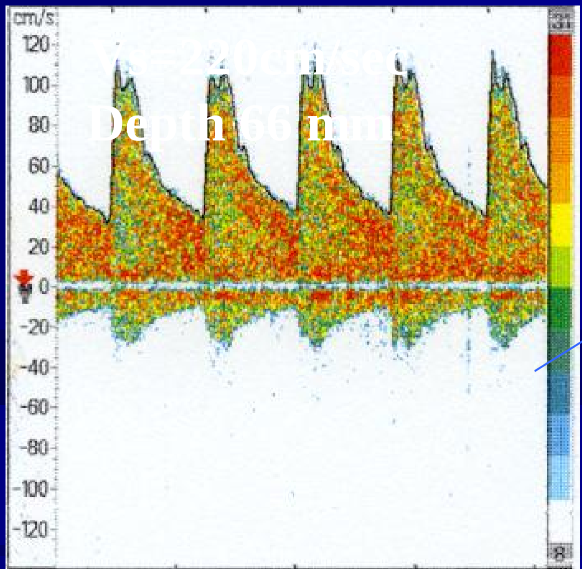
L MCA depth
52-42mm

ase three

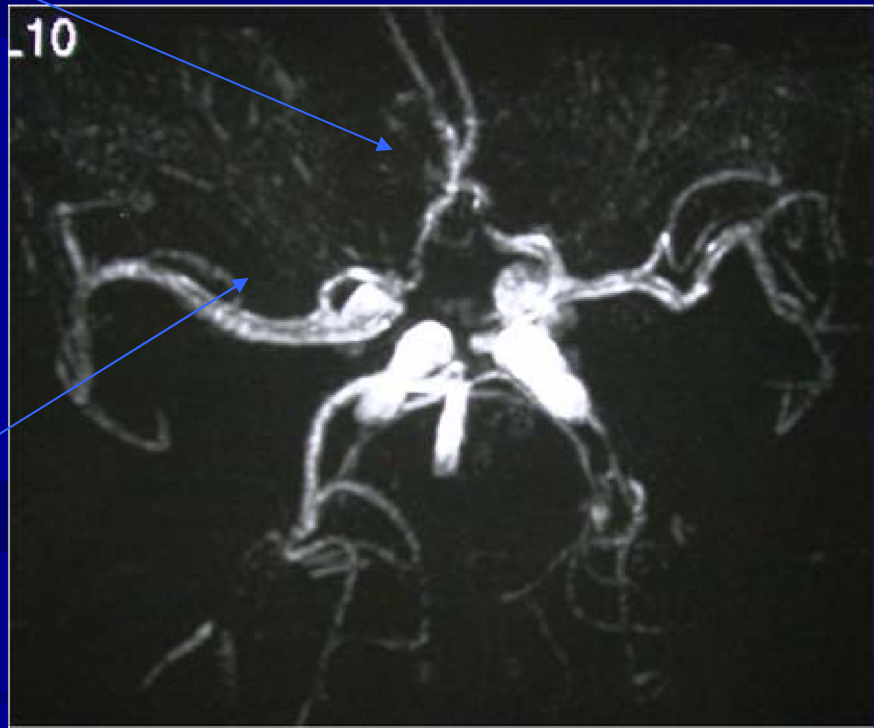
R ACA



R MCA



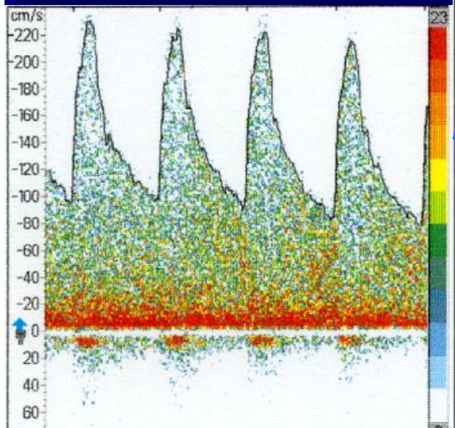
Vs=100cm/sec
Depth 56 mm



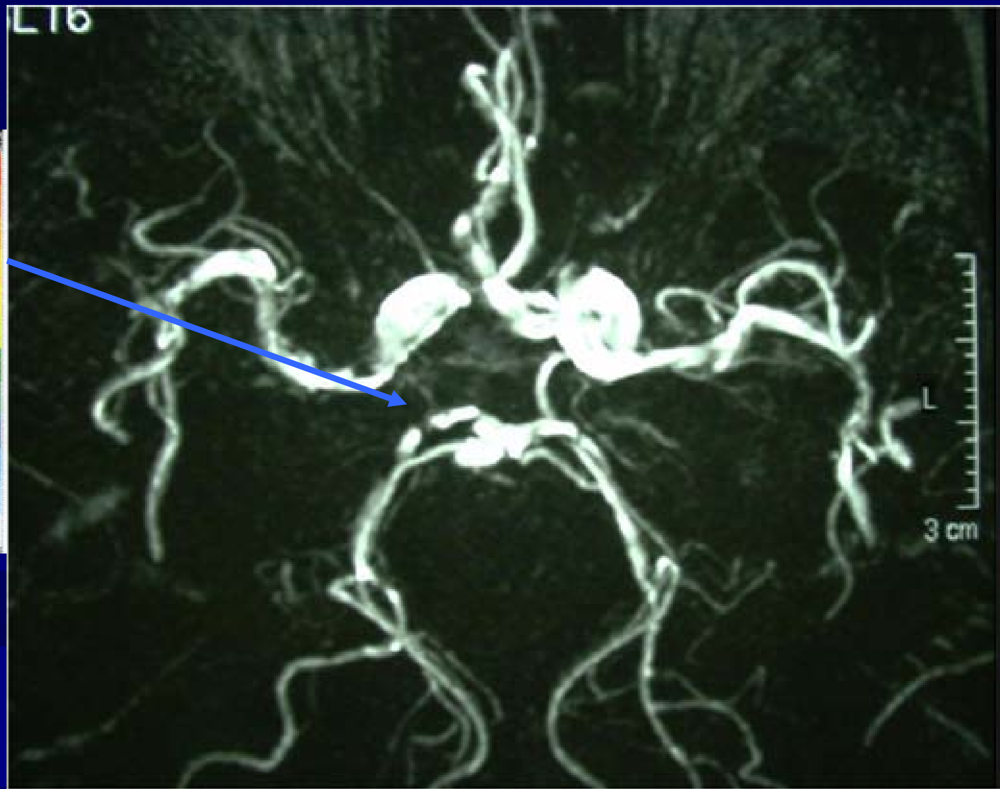
MRA-Bilateral ACA stenosis

Case four

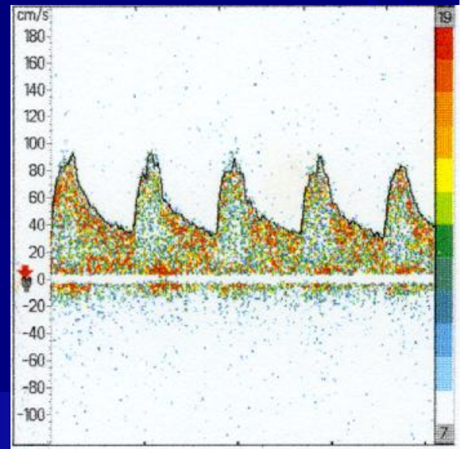
R PCA



Vs=220cm/sec
Depth 62 mm



L PCA

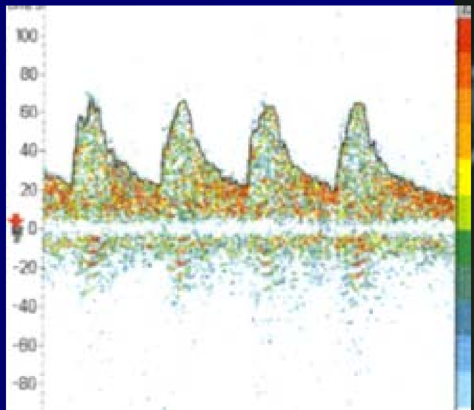


Vs=80 cm/sec
Depth 66mm

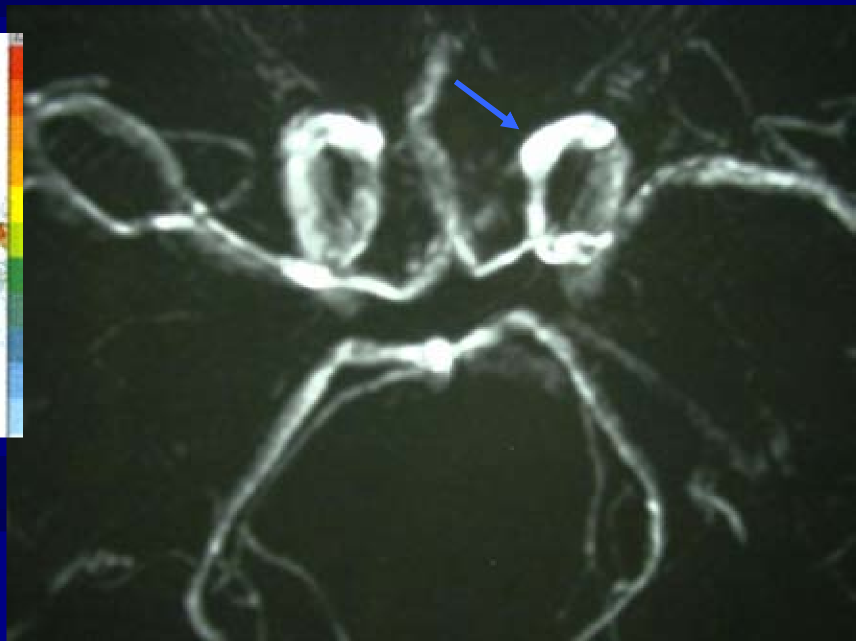
MRA-RPCA severe stenosis

Case five

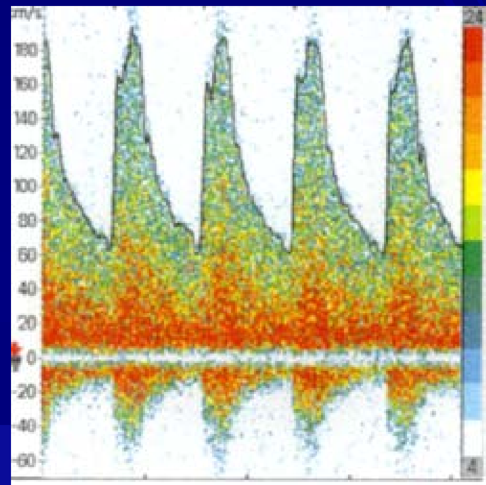
R siphon A



Vs=70cm/sec
Depth 68 mm



L siphon A



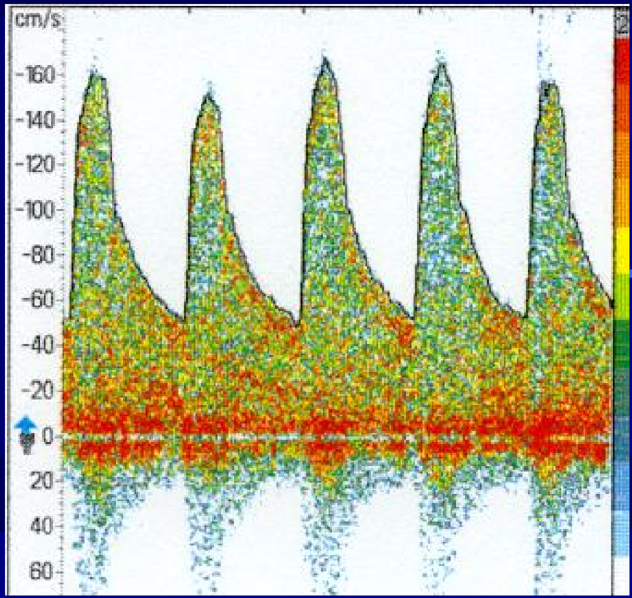
Vs=200cm/sec
Depth 70 mm

MRA- left siphon A stenosis

Through orbital window

Case six

R VA



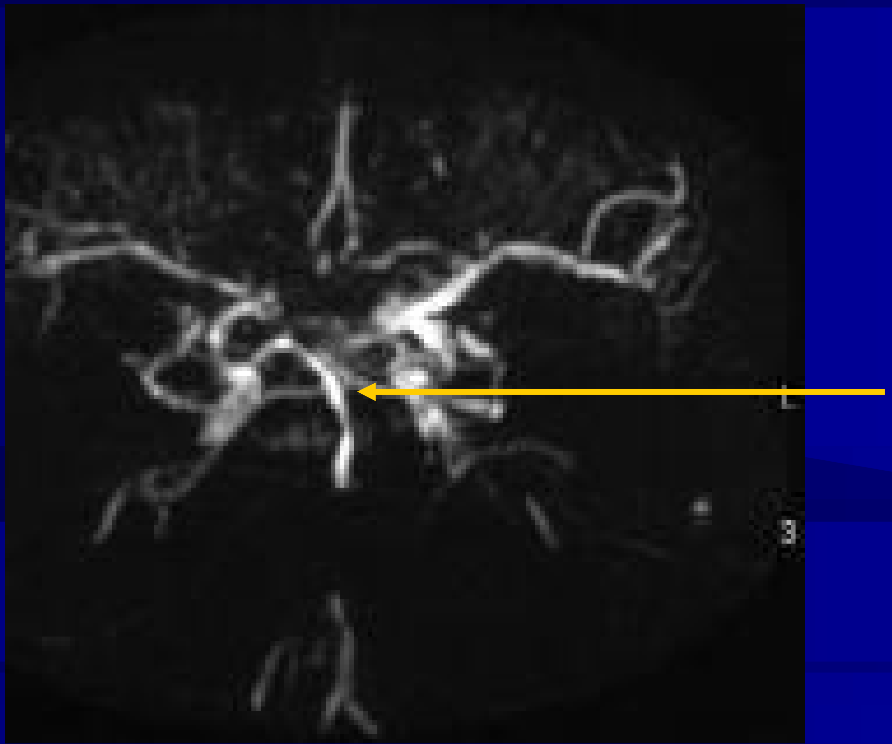
No flow

L VA

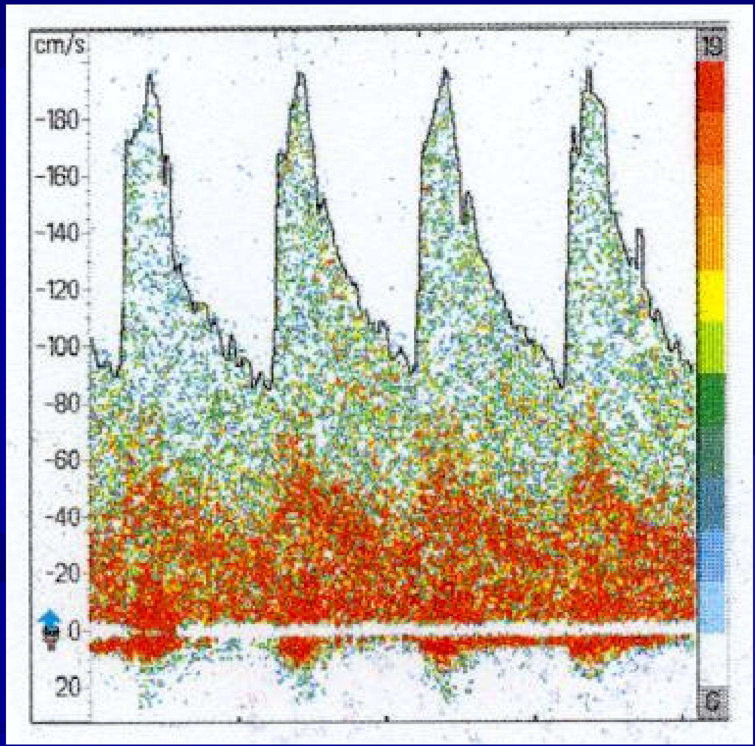
Vs=160cm/sec
Depth 70 mm

MRA-right VA stenosis, LVA occlusion

Case seven

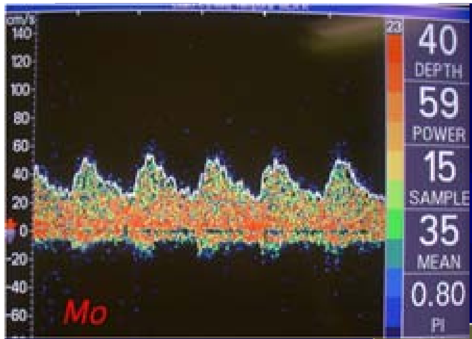


MRA-BA stenosis

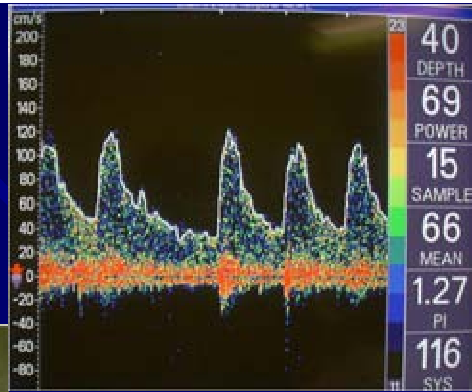


Vs=190 cm/sec
Depth 102 mm

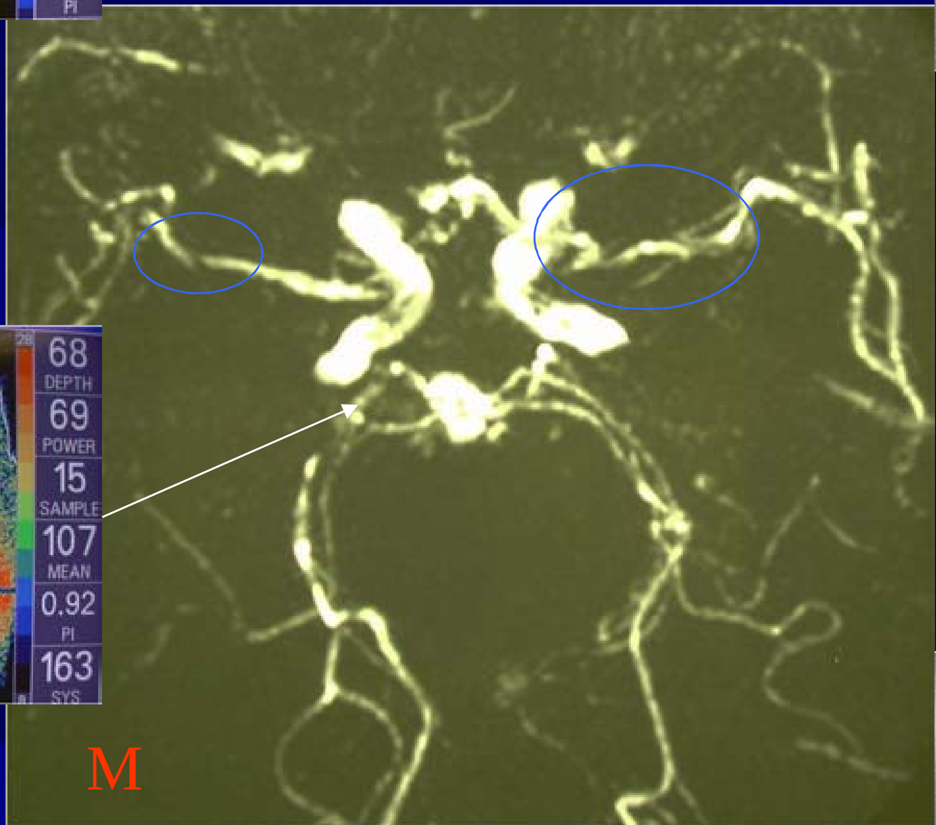
Case eight

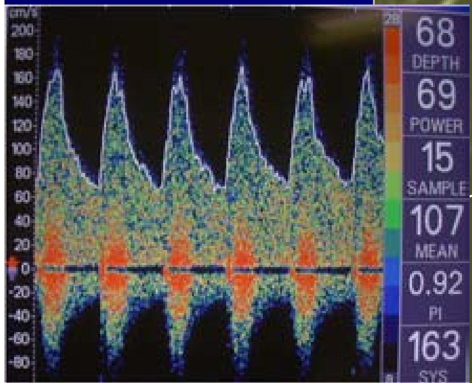


L MCA

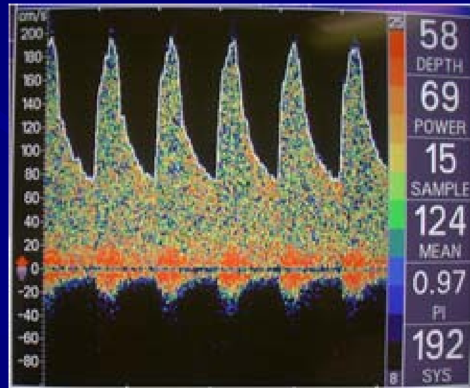


Depth 40mm, Vs=130

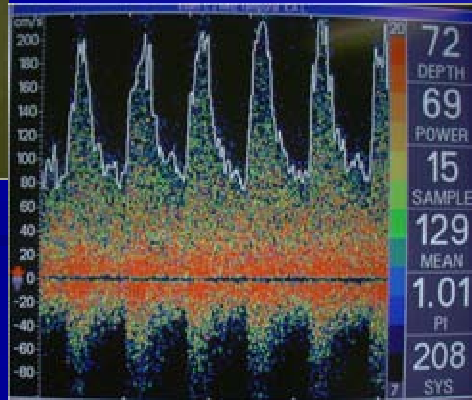




R PCA



Depth 58 mm, Vs=200



MRA multi stenosis

Depth 68, Vs=170

AJNR Am J Neuroradiol 22:1743–1747, October 2001

Importance of Angle Correction in the Measurement of Blood Flow Velocity with Transcranial Doppler Sonography

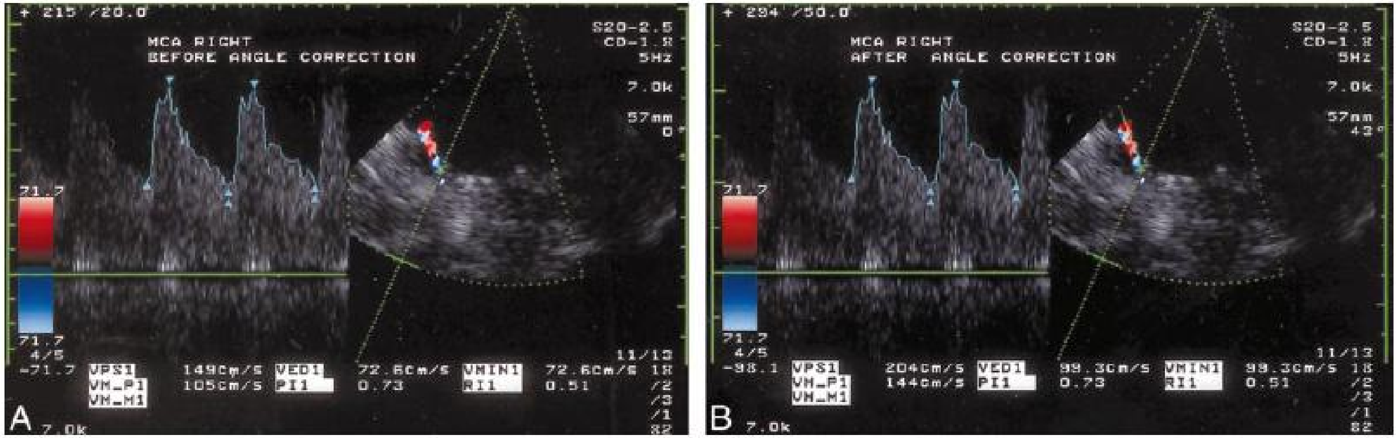
Jaroslaw Krejza, Zenon Mariak, and Viken L. Babikian

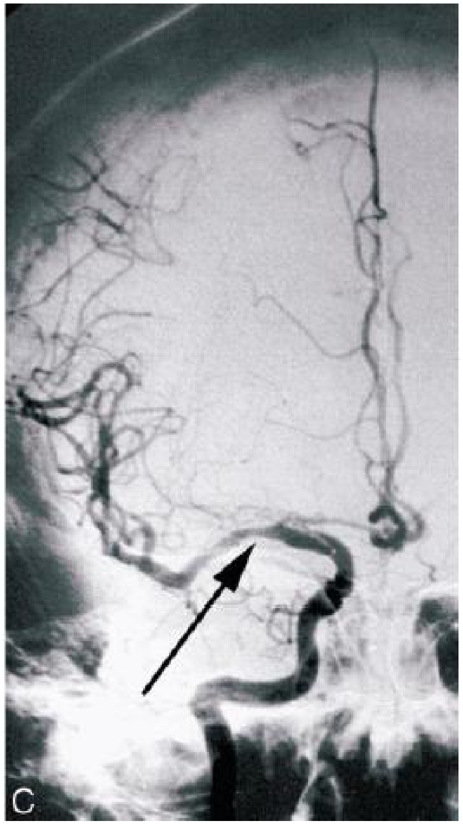
BACKGROUND AND PURPOSE: The angle of insonation cannot be assessed with conventional transcranial Doppler sonography. Findings in healthy control subjects suggest that the angle is relatively small in routine clinical practice. Data regarding the angle in middle cerebral artery (MCA) stenosis are scarce. In this study, the angle and its effect on flow velocity measurements were assessed with transcranial color Doppler sonography in patients with MCA stenosis.

METHODS: Eighteen patients (median age, 53 y; age range, 22–72 y) who satisfied qualifying criteria (eg, angiographically revealed unilateral MCA stenosis of ≥50%) were selected from 149 consecutive patients enrolled in a prospective study of transcranial color Doppler sonography and cerebral digital subtraction angiography. All had active neurologic symptoms. The angle of insonation and peak systolic and mean flow velocities in both MCAs were measured from videotapes generated at sonography.

RESULTS: The mean angle of insonation was 47 ± 11° (range, 19–64°) on the stenotic side and 34 ± 18° on the contralateral side ($P < .05$). Angle-corrected velocities were higher than uncorrected ones. Differences between angle-corrected and uncorrected peak systolic and mean flow velocities on the stenotic side were 46.6% and 45.9%, respectively, of uncorrected values. Differences between corrected and uncorrected peak systolic and mean velocities were larger on the stenotic side compared with those on the contralateral side ($P < .05$).

CONCLUSION: In patients with moderate or severe MCA stenosis, the angle of insonation can be substantial and cause large errors when flow velocities are measured without angle correction.





AJNR Am J Neuroradiol 22:1743–1747, October 2001

FIG 1. Comparison between angle-corrected and uncorrected flow velocities and angiographic findings in a 54-year-old woman with MCA stenosis.

A and *B*, At TCCD sonography, the sample volume is placed approximately 10 mm from the internal carotid artery bifurcation and within the color image of the right MCA. The velocity spectrum is adjacent to the left of the image of the artery. The uncorrected peak systolic velocity is 149 cm/s (*B*).

C, Angiogram shows a lesion causing a stenosis of more than 50% (*arrow*) in the right MCA M1 segment. The angle-corrected peak systolic velocity is 204 cm/s.

Comparison of angle-corrected and uncorrected blood flow velocities in 18 patients with MCA stenosis of ≥50%

Velocity (cm/s)	Angle Corrected		Uncorrected	
	Ipsilateral	Contralateral	Ipsilateral	Contralateral
Peak systolic	195 ± 56*	122 ± 27	133 ± 38	101 ± 22
Mean	124 ± 39*	80 ± 20	85 ± 27	66 ± 17
End diastolic	88 ± 37*	51 ± 13	60 ± 25	42 ± 11

Note.—Values are the mean ± SD.

* Values are significantly different from uncorrected ipsilateral velocities.

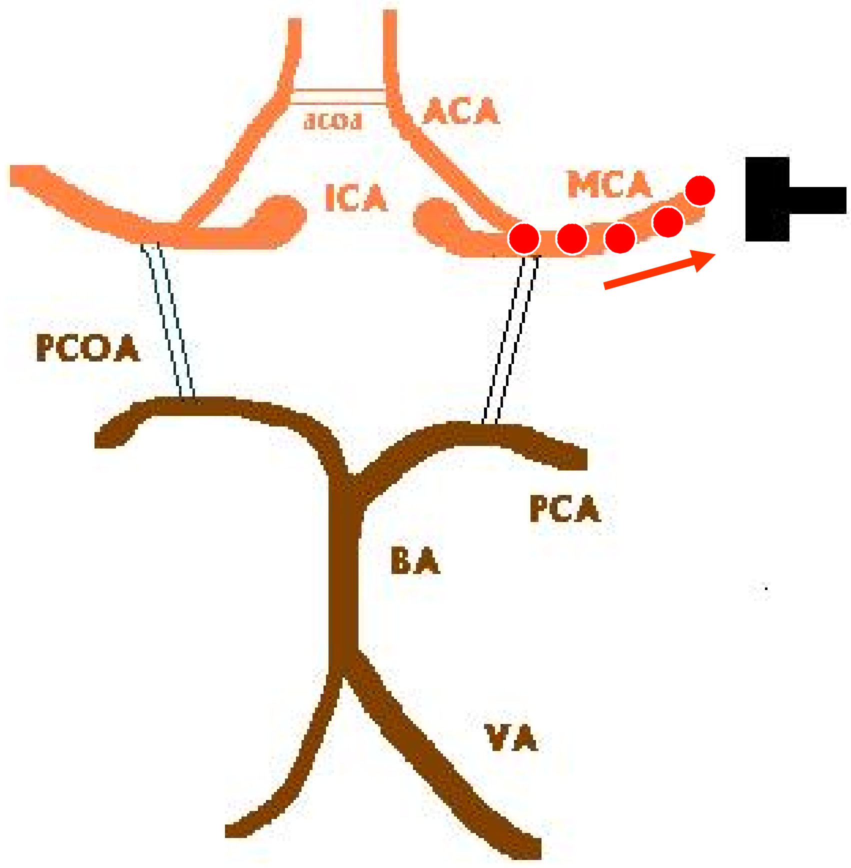
AJNR Am J Neuroradiol 22:1743–1747, October 2001

The optimal values of flow velocity on transcranial Doppler in grading severity of middle cerebral artery stenosis

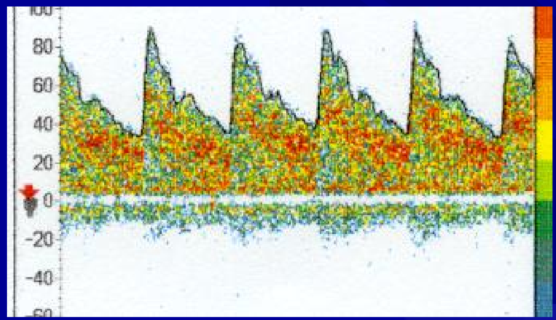
Methods

- Asymptomatic patients
- Transcranial Doppler (TCD)
- Magnetic resonance angiography (MRA)
- Exclusion: patients with inadequate temporal window, atrial fibrillation or extracranial carotid stenosis

Insonation of MCA through temporal window



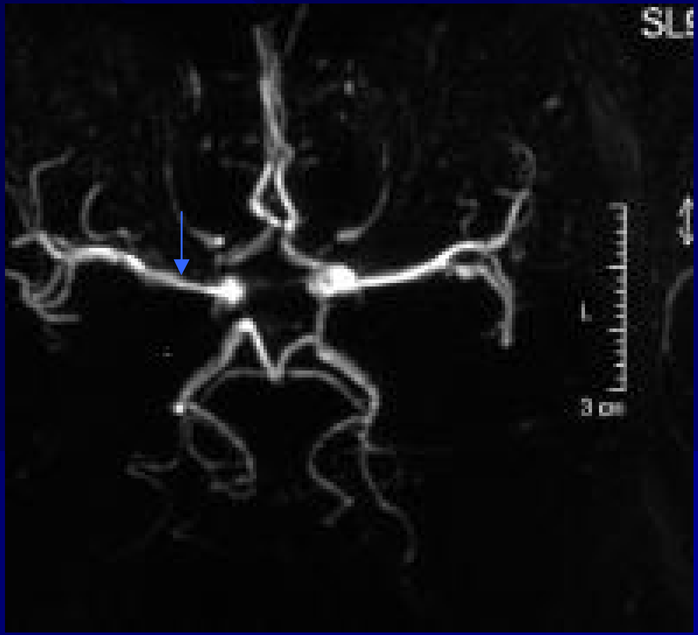
Peak systolic velocity (cm/sec)

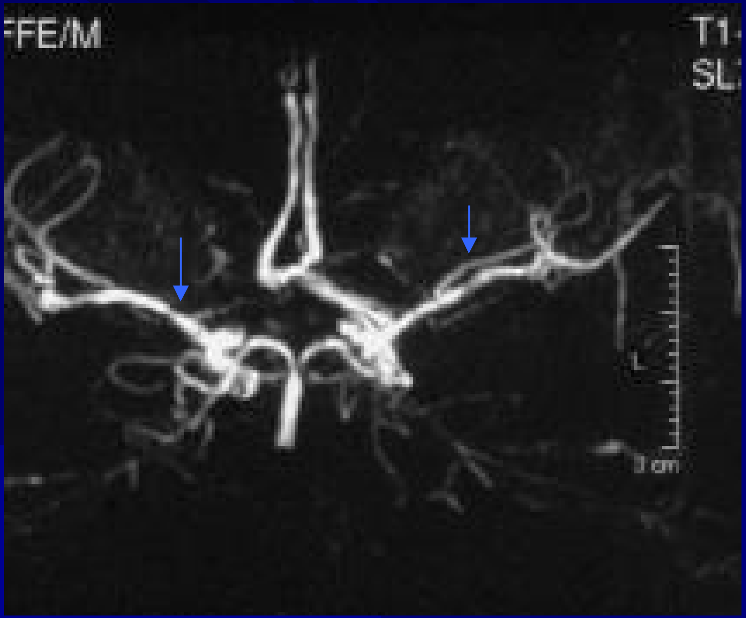


- From proximal to distal
- Proximal depth 64-68 mm
- Distal depth 36-42 mm (no signal can be detected)
- With interval of 4mm

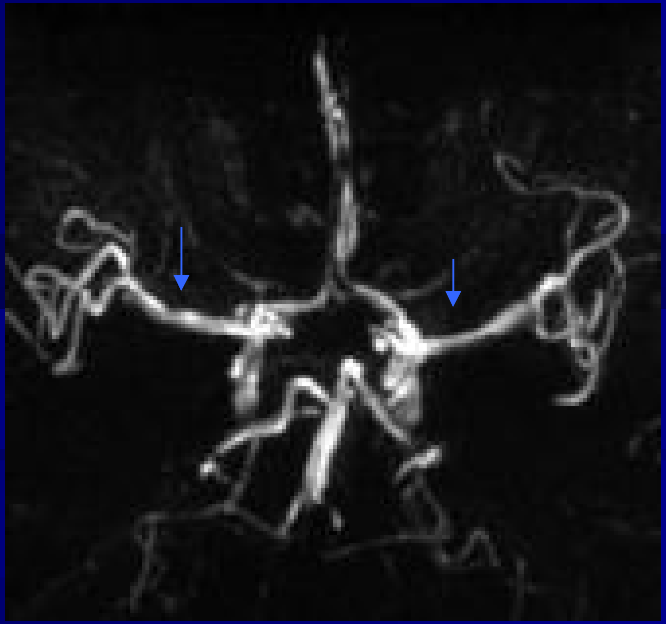
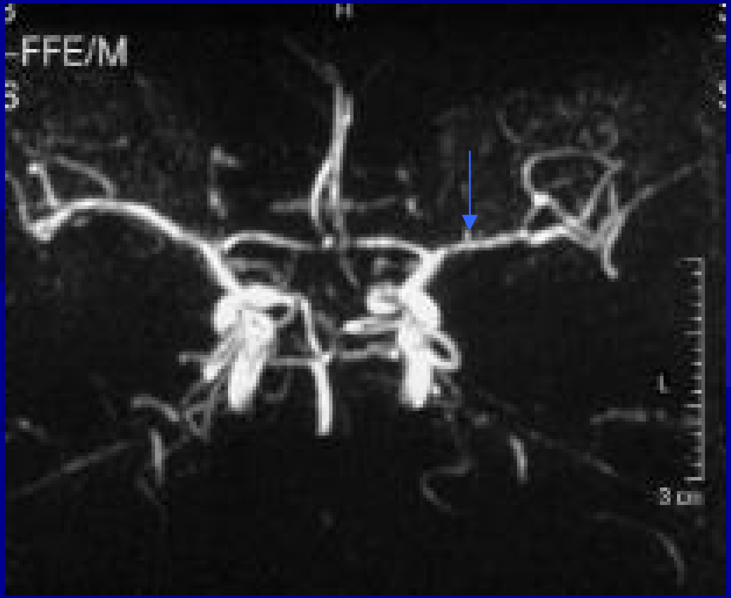
Grading of MCA stenosis on MRA

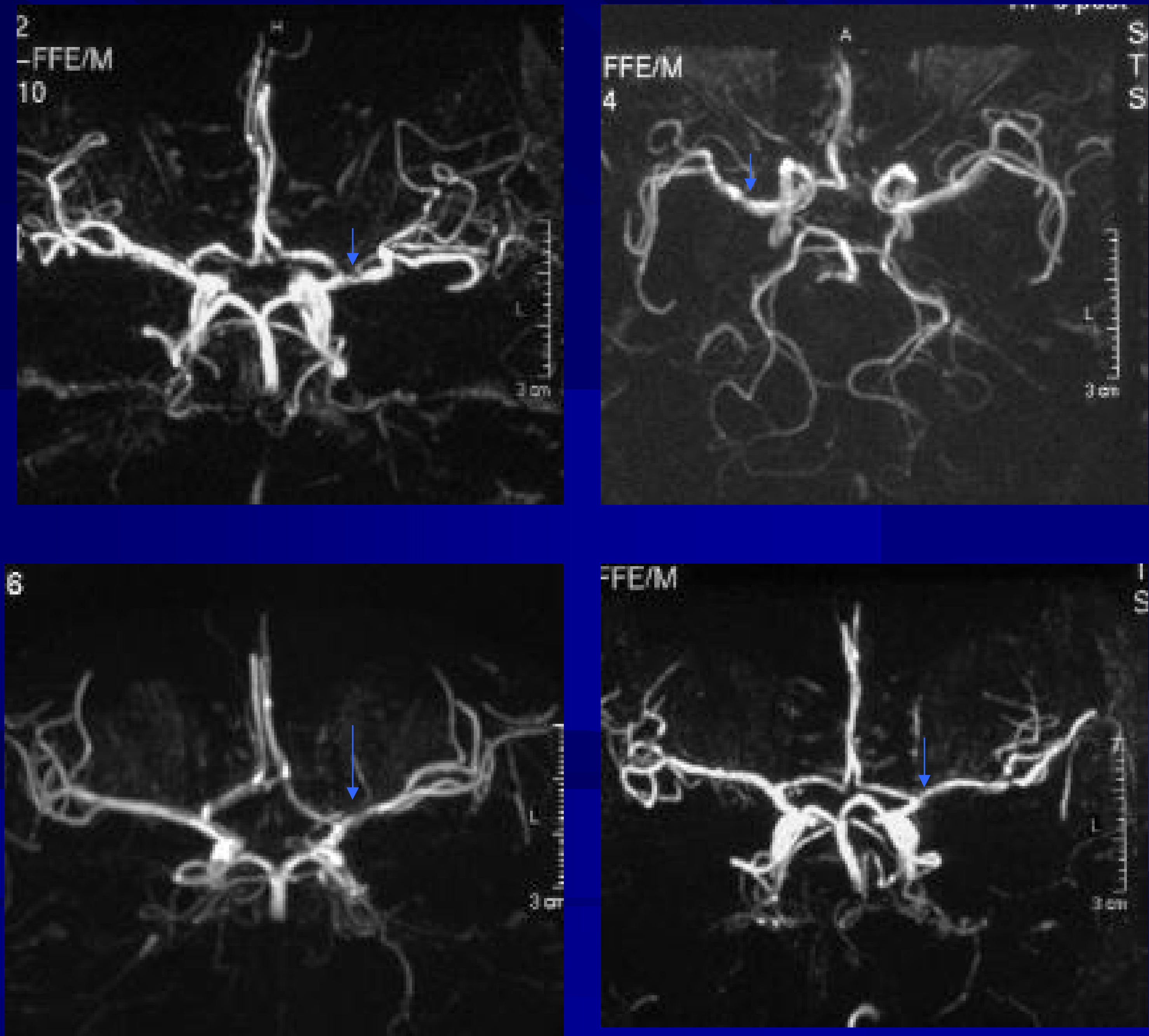
- Each MCA was measured respectively
- According to the lumenal diameter stenosis:
  - Normal-mild: <50%
  - Moderate: 50%-75%
  - Severe: >75% and void of flow signal



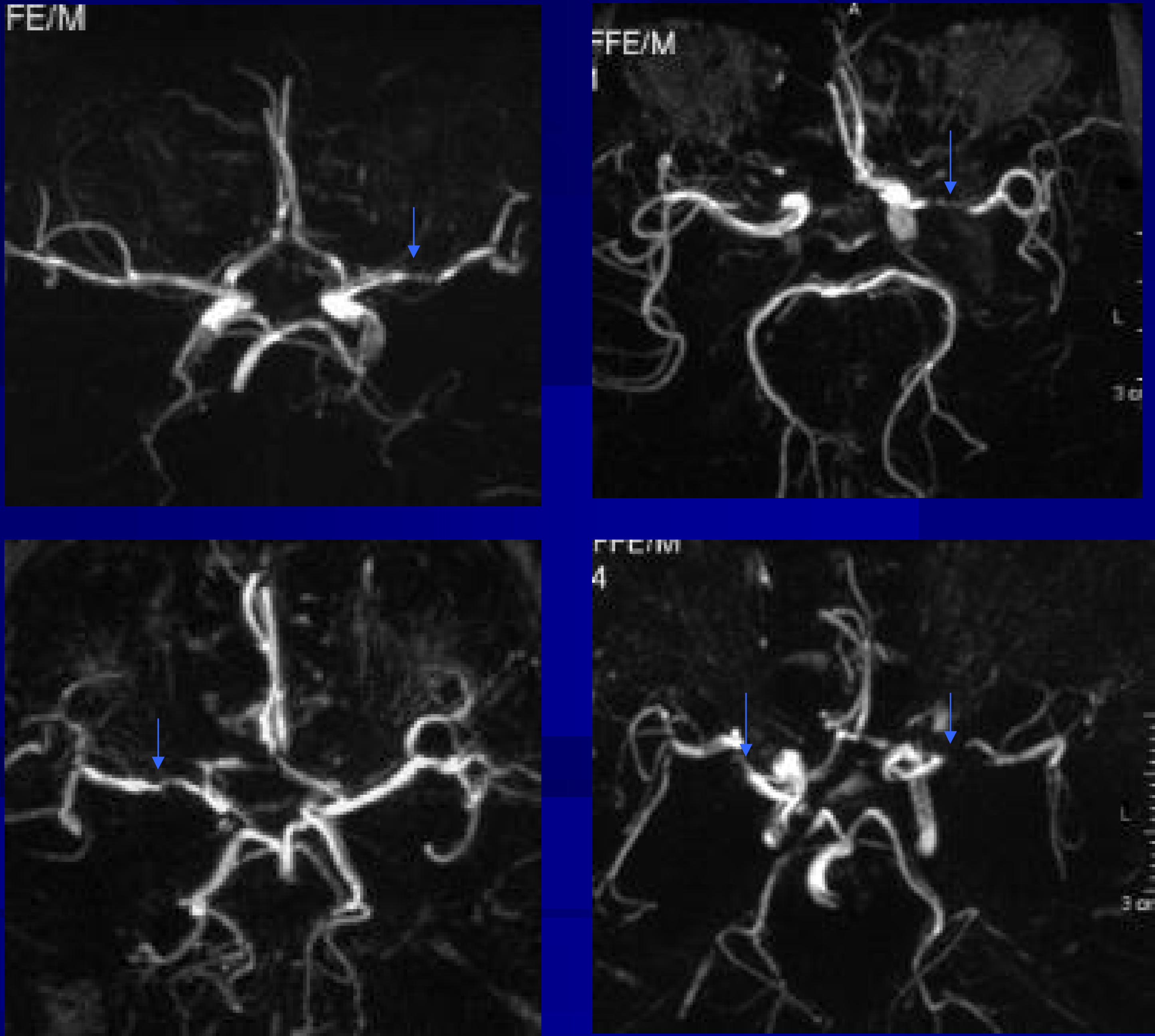


Mild stenosis



Moderate



Severe

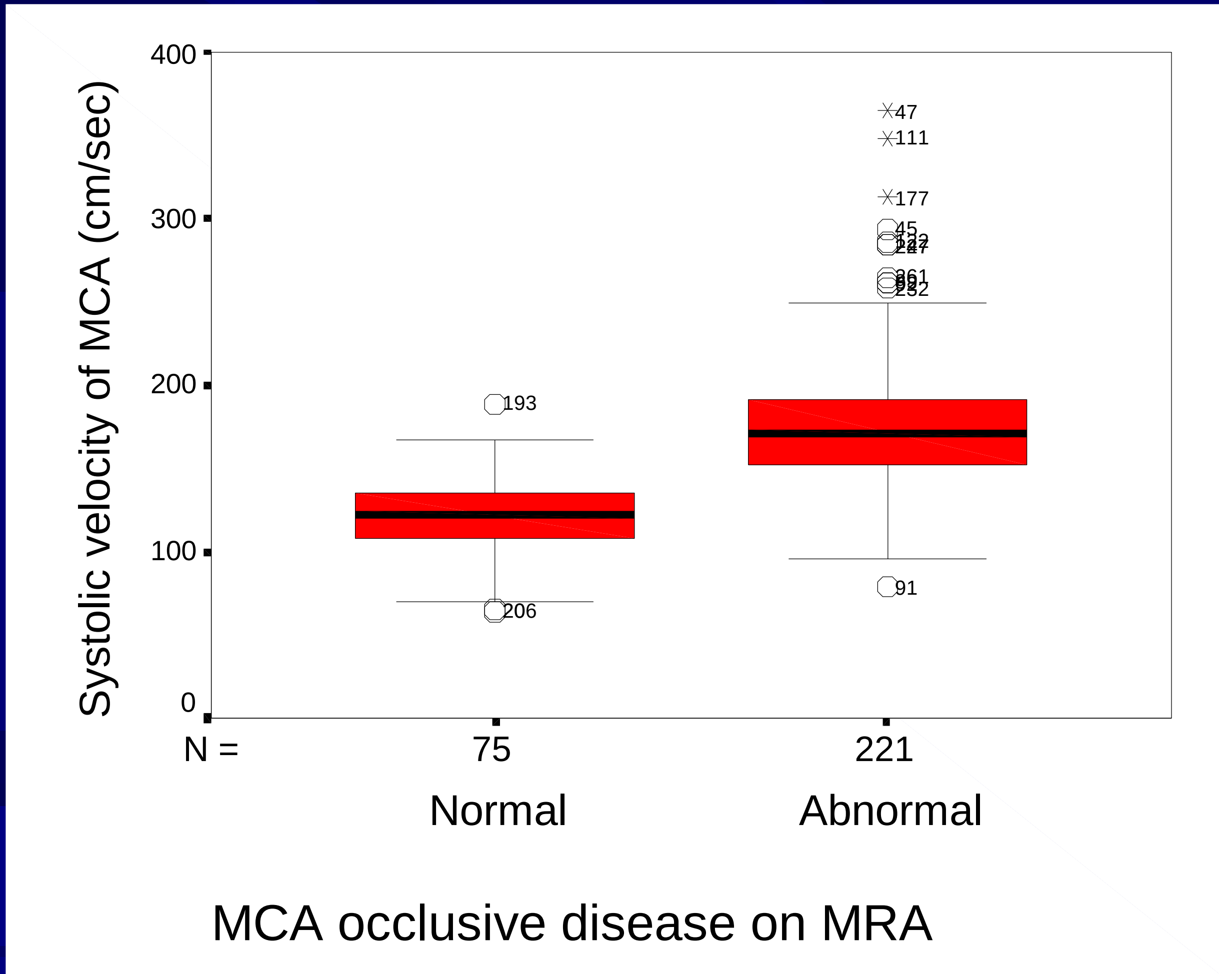
TCD flow velocity in normal or abnormal MCA groups measured by MRA

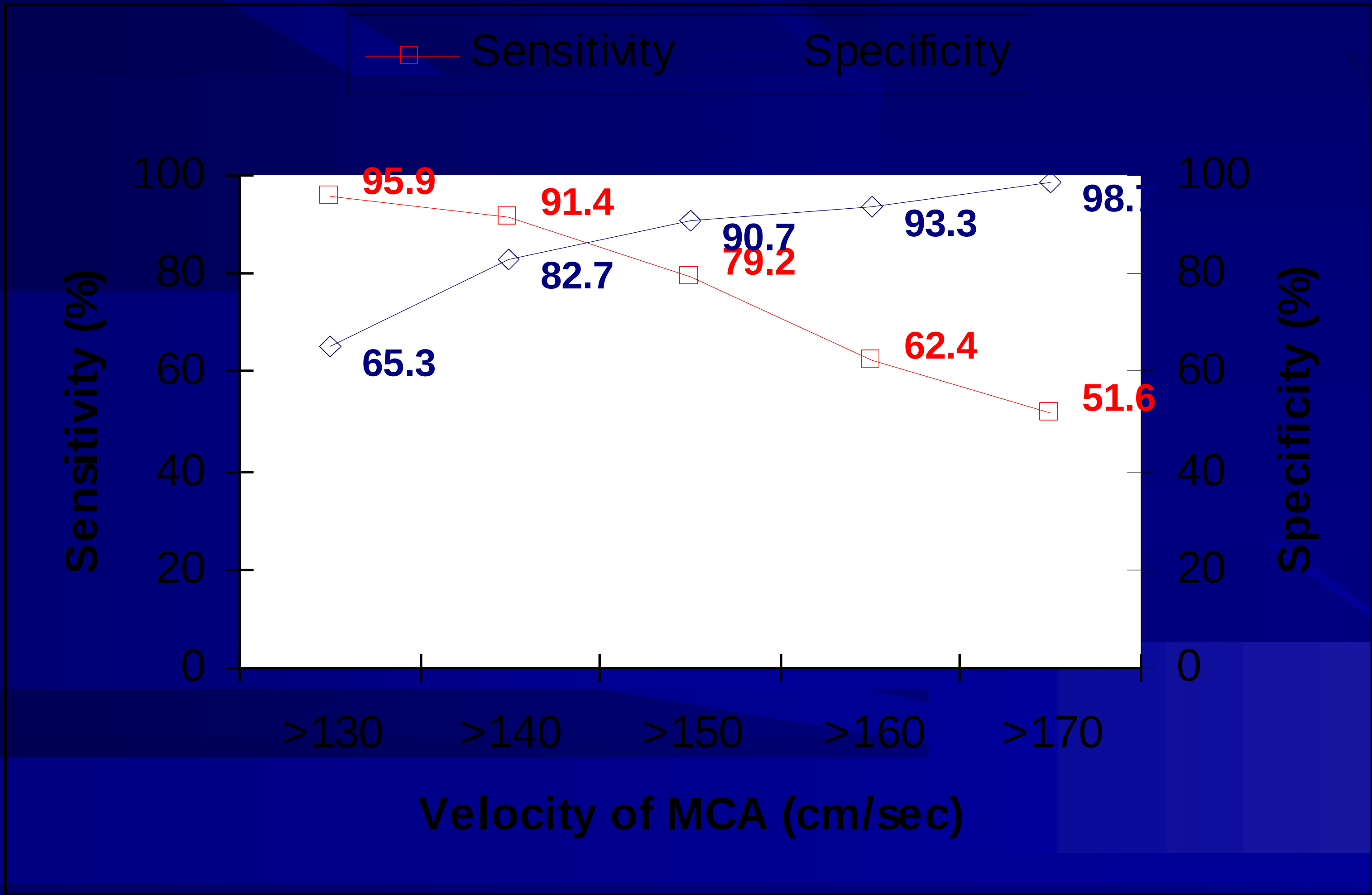
Report

MCA Vs (cm/sec) (March 2001)

MRA MCA stenosis	Mean	N	Std. Deviation
Normal	121.91	75	22.56
Abnormal	177.35	221	40.70
Total	163.30	296	44.12

Test feasibility of assess MCA abnormal use TCD velocity





Sensitivity
Specificity
Sensitivity (%)
Specificity (%)
100
80
60
40
20
0
95.9
91.4
79.2
62.4
51.6
65.3
82.7
90.7
93.3
98.7
>130
>140
>150
>160
>170
Velocity of MCA (cm/sec)

MRA MCA stenosis * TCD MCA stenosis (Vs=140 cm/sec)

		MCA Vs=140 cm/sec		Total
		Normal	Abnormal	
MRA MCA stenosis	Normal	62	13	75
	Abnormal	19	202	221
Total		81	215	296
Sensitivity	91.40%	False positive	17.30%	
Specificity	82.70%	False negative	8.60%	

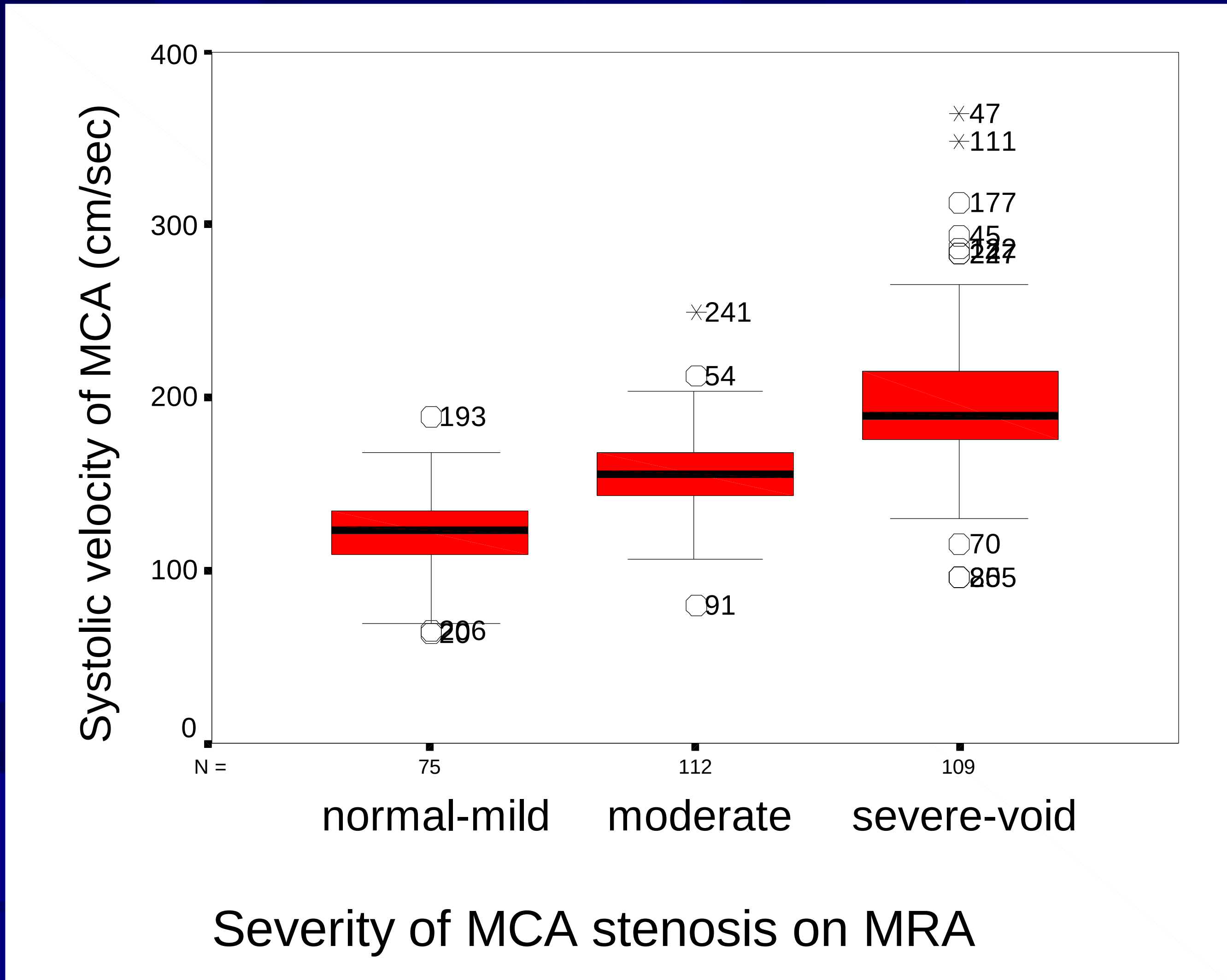
TCD flow velocity corresponding to different severity on MRA

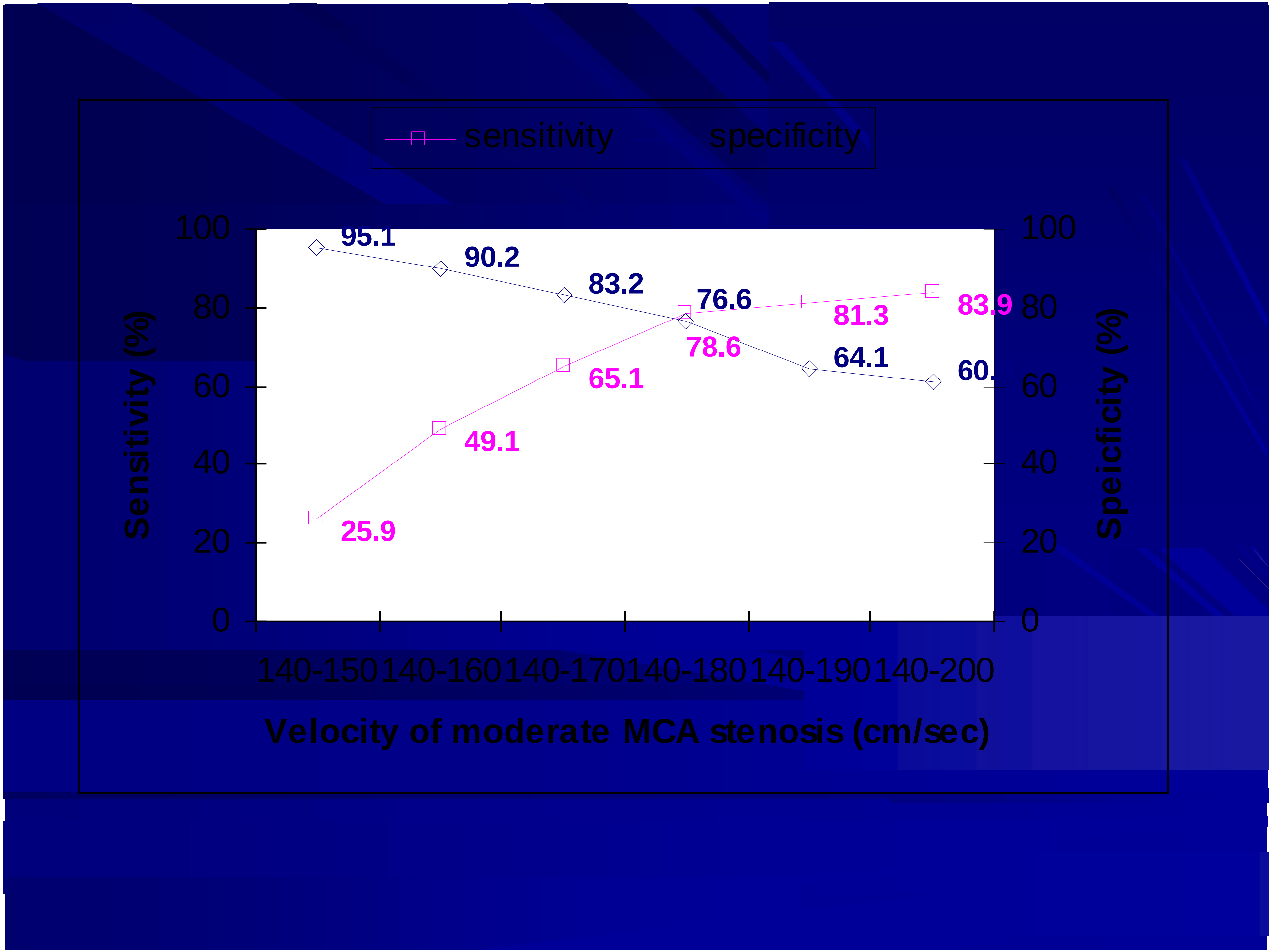
Report

MCA Vs (cm/sec)

MRA MCA grade	Mean	N	Std. Deviation
normal-mild	121.83	75	22.52
moderate	155.96	112	21.62
severe-void	199.39	109	43.86
Total	163.30	296	44.12

Test feasibility of assess severity of MCA stenosis use TCD velocity





sensitivity
specificity
Sensitivity (%)
Speicficity (%)
100
80
60
40
20
0
95.1
90.2
83.2
76.6
64.1
60.
25.9
49.1
65.1
78.6
81.3
83.9
140-150
140-160
140-170
140-180
140-190
140-200
Velocity of moderate MCA stenosis (cm/sec)

ASSESSMENT: TRANSCRANIAL DOPPLER ULTRASONOGRAPHY

Report of the Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology

Neurology 2004;62(9):1468

Summary of findings
Intracranial Steno-Occlusive Disease

INDICATION	SENSITIVITY (%)	SPECIFICITY (%)	REFERENCE STANDARD
Intracranial Steno-Occlusive Disease:			Conventional angiography
Anterior Circulation	70-90	90-95	
Posterior Circulation Occlusion	50-80	80-96	

Summary of findings Intracranial Steno-Occlusive Disease (Continued)

INDICATION	SENSITIVITY (%)	SPECIFICITY (%)	REFERENCE STANDARD
MCA	85-95	90-98	
ICA, VA, BA	55-81	96	

Recommendation: Data are insufficient to establish TCD criteria for greater than 50% stenosis or for progression of stenosis in intracranial arteries (Type U).

Summary of findings
Acute cerebral infarction

INDICATION	SENSITIVITY (%)	SPECIFICITY (%)	REFERENCE STANDARD
Acute cerebral infarction	85-95	90-98	

Recommendation: TCD is probably useful for the evaluation of patients with suspected intracranial steno-occlusive disease, particularly in the ICA siphon and MCA (Type B, Class II evidence).

The relative value of TCD compared with MRA or CTA remains to be determined (Type U).

Data are insufficient to give a recommendation regarding replacing conventional angiography with TCD (Type U).

Summary of findings TCCS Ischemic Cerebrovascular Disease

(Continued)

INDICATION	SENSITIVITY (%)	SPECIFICITY (%)	REFERENCE STANDARD
Intracranial Steno-Occlusive Lesions			
Any	Up to 100	Up to 83	

Some studies describing diagnostic criteria for ?50% stenosis of middle cerebral artery.

Study	Diagnostic criteria	Validation study
De Bray et al[58]	PSF>3kHz, segmental flow acceleration by 20%	DSA
Zanette et al[59]	Side-to-side asymmetry	DSA
Carmelingo et al[60]	MFV>80cm/s	DSA
Rorick et al[61]	MFV>80cm/s	DSA
Gao et al[62]	PSV>140cm/s	MRA
Suwanwela et al[63]	PSV>140cm/s, MFV>80cm/s	CTA
Felberg et al[64]	MFV>100cm/s, MFV ratio of post-stenotic to pre-stenotic segment 2:1	DSA
Bang et al[65]	MFV>80cm/s	DSA
Tsivgoulis et al[66]	For severe steno-occlusive lesions in acute stroke. TIBI grading and indirect signs	CTA
Hao et al[67]	Scoring system- PSV<140 to ?300cm/s; hemodynamic scale; side-to-side difference; spectrum scale.	MRA

Sharma VJ et al. unpublished

PSF- peak systolic frequency; MFV- mean flow velocity;

iews & Reviews

r's Curve: Clinical
f a Classic
odel

Andrei V. Alexandrov, MD

The S
Implicat
Hemodyna

Alexandrov AV
The Spencer's curve: clinical implications
of a classic hemodynamic model.
J Neuroimaging 2007;17:6-10.
DOI: 10.1111/j.1552-6569.2006.00083.x

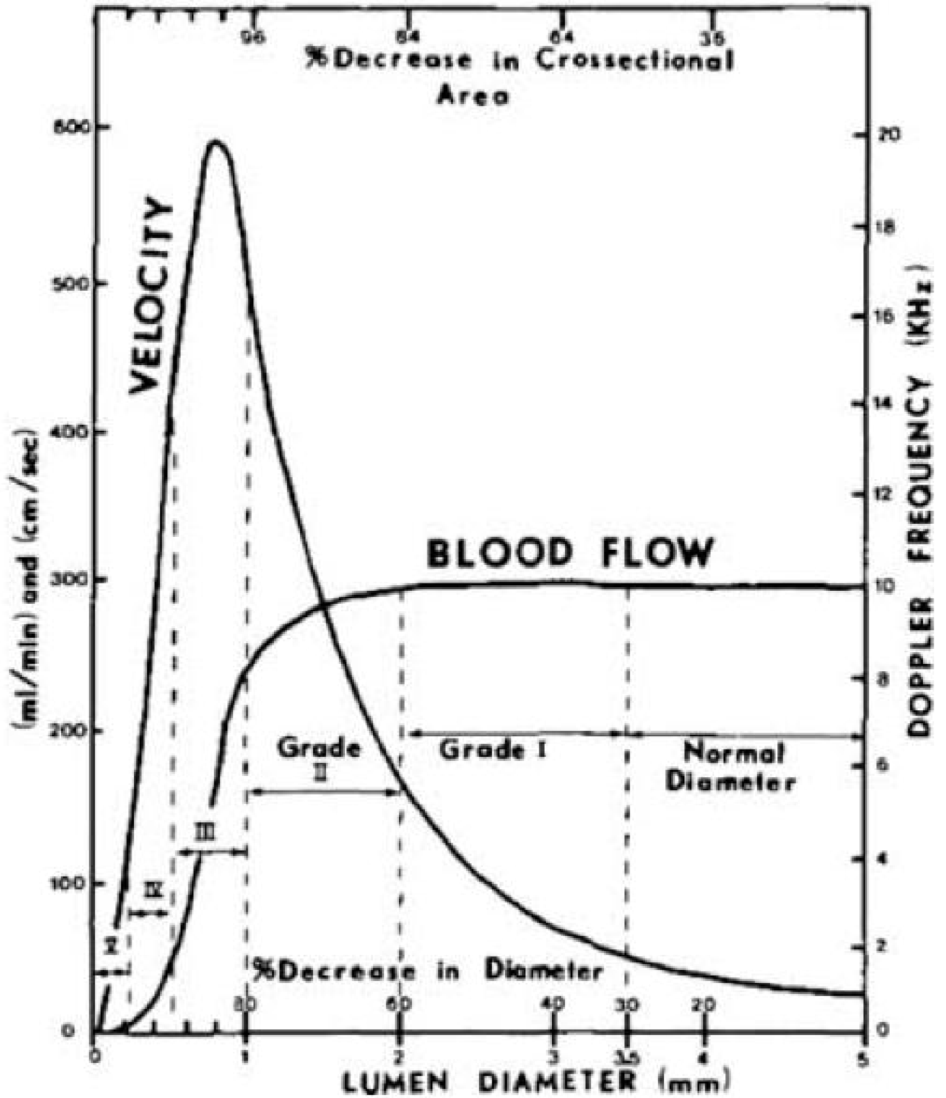


Fig 1. The Spencer's curve (reproduced with permission from Spencer MP, Reid JM. Quantitation of carotid stenosis with continuous wave Doppler ultrasound. *Stroke* 1979;10:326-330).

(Velocity +) Criteria needed

- Why new criteria?

  The current criteria for MCA stenosis yield variable accuracy

  PPV=55% in Stroke outcomes and neuroimaging of Intracranial Atherosclerosis (SONIA) study.

  Neurology 2007;68 (24):2099-106

Pilot Study of New Diagnostic Criteria for Middle Cerebral Artery Stenosis by Transcranial Doppler

Qing Hao, MD, Shan Gao, MD, Thomas Wai Hong Leung, FRCP, Ming Hui Guo, MD, Yong You, MD, Ka Sing Wong, MD

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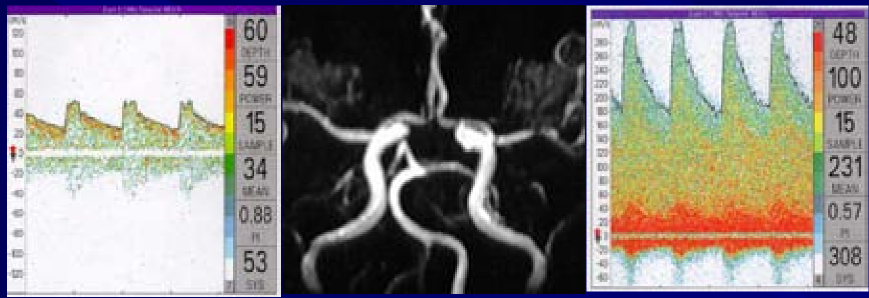
J Neuroimaging 2010;20:122-129.

Background



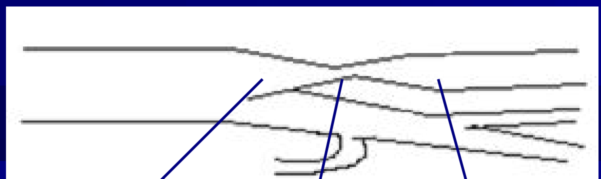
velocity

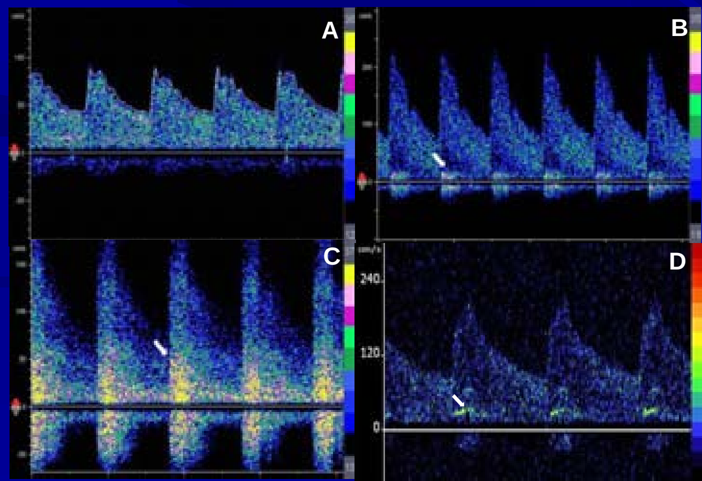
waveform

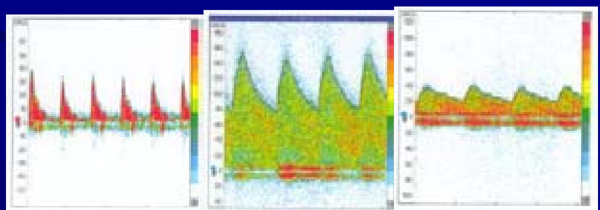
TCD

Differences with homonymous artery/ other ipsilateral arteries

spectrum







Purpose

Establish new diagnostic criteria
for MCA stenosis
using MRA and DSA
as the confirmative methods

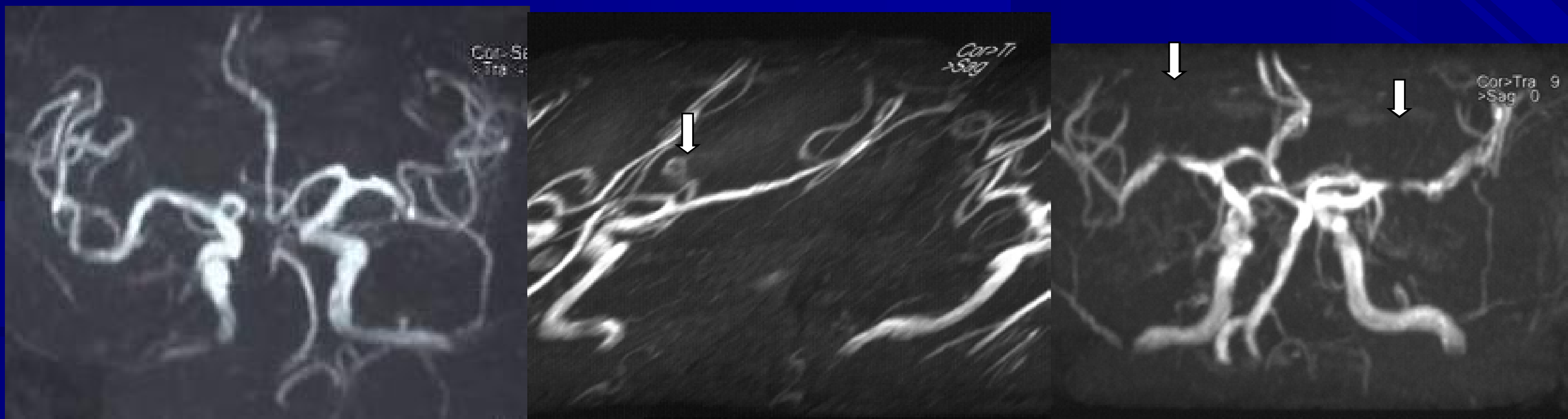
Journal of Neuroimaging
Early View (Articles online in advance of print)
Published Online: 29 Jan 2009

Method

MRA : Severity of MCA stenosis was categorized as

- normal-mild (<50% diameter reduction),
- moderate (50%-75% diameter reduction),
- severe (>75% diameter reduction and signal void)

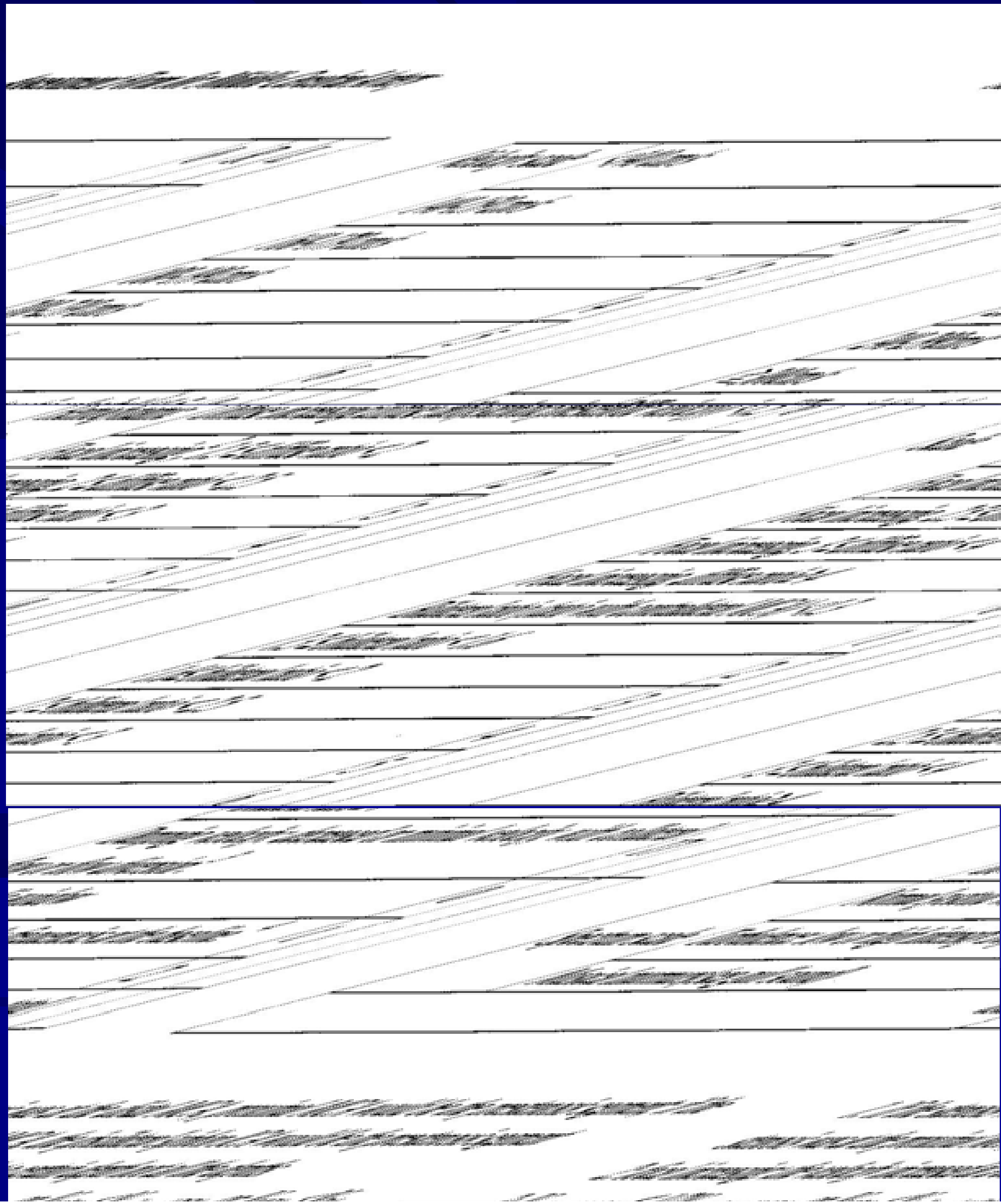
(thesis page 44)



Method

<u>TCD</u> :

A composite score for MCA stenosis was calculated from the [assessment form](#)
(thesis page 50)



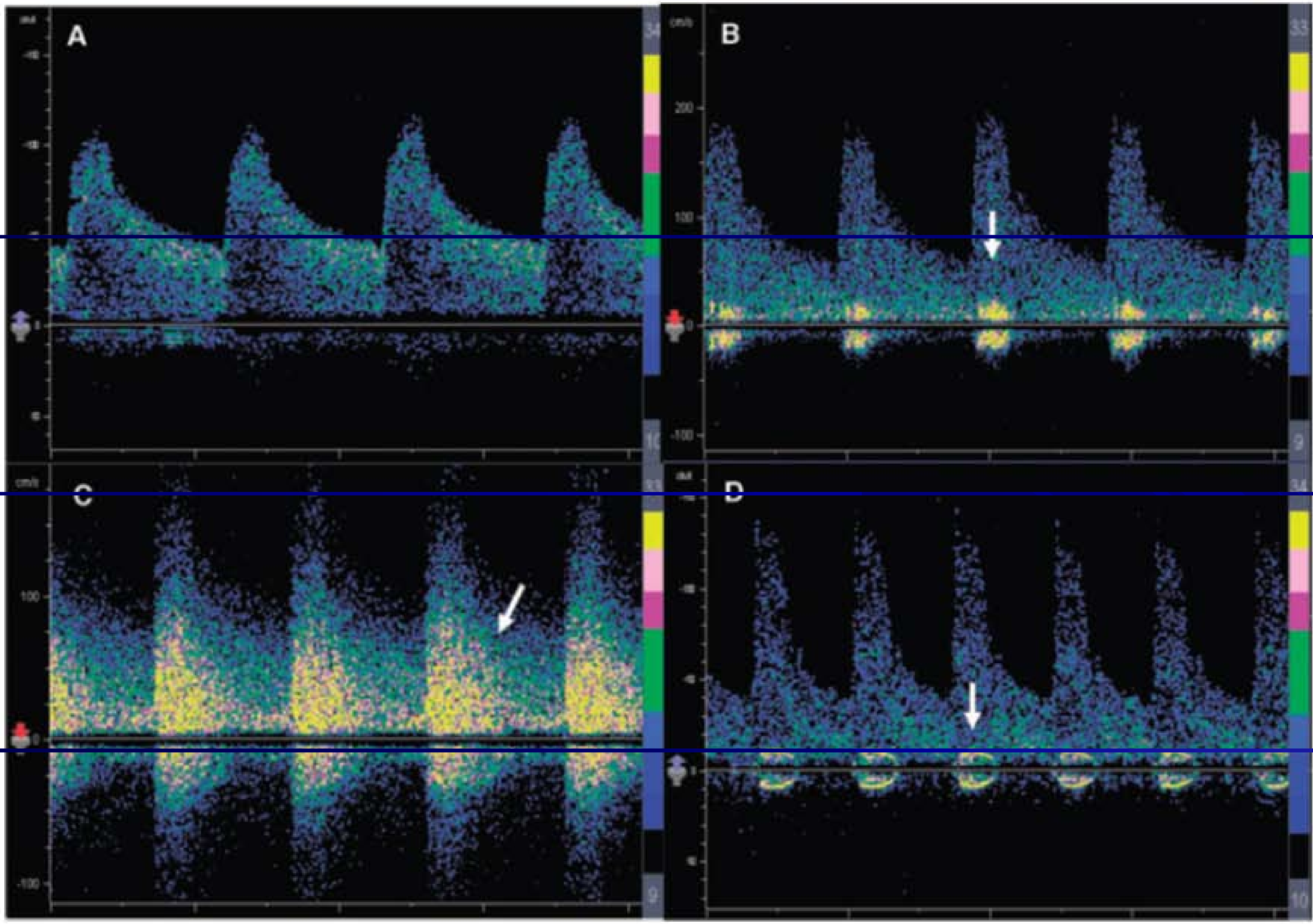


Fig 2. The different spectrum pattern: (A) Normal; (B) Low frequency turbulence; (C) High frequency turbulence; (D) Musical murmurs.

Result 2 **Score had much balanced accuracy than PSV or MV using DSA as the confirmative method.**

Table 2: comparison of the cutoff value for <50% and ?≥50% stenosis

	Area under ROC curve (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
score=4	0.836(0.76-0.912)	76.6(61.6-87.2)	90.6(84.6-94.4)	70.6(56.0-82.1)	92.9(87.3-96.2)
score=5	0.833(0.754-0.913)	72.3(57.1-83.9)	94.3(89.2-97.2)	79.1(63.5-89.4)	92.0(86.5-95.5)
score=6	0.768(0.677-0.86)	57.4(42.3-71.4)	96.2(91.6-98.5)	81.8(63.9-92.4)	88.4(82.5-92.6)
PSV=170cm/s	0.761(0.673-0.850)	61.7(46.4-75.1)	90.6(84.6-94.4)	65.9(50.0-79.1)	88.9(82.8-93.0)
PSV=180cm/s	0.764(0.676-0.853)	61.7(46.4-75.1)	91.2(85.4-94.9)	67.4(51.3-80.5)	89.0(82.9-93.1)
PSV=190cm/s	0.765(0.674-0.856)	57.4(42.3-71.4)	95.6(90.8-98.1)	79.4(61.6-90.7)	88.4(82.4-92.6)
MV=100cm/s	0.770(0.684-0.856)	66.0(50.6-78.7)	88.1(81.7-92.5)	62.0(47.2-75.0)	89.7(83.6-93.8)
MV=110cm/s	0.760(0.670-0.850)	59.6(44.3-73.3)	92.5(86.9-95.9)	70.0(53.3-82.9)	88.6(82.5-92.8)
		59.6(44.3-	95.0(90.0-	77.8(60.4-	

Conclusions

- **The optimal cutoff score for <50% and ?50% stenosis was 3 with the PPV of 72.3% (95% confidence interval [CI]: 65.3% to 78.5%) and negative predictive value (NPV) of 89.5% (95% CI: 85.9% to 92.3%), for moderate and severe stenosis was 6 with the PPV of 85.9% (95% CI: 76.7% to 92.0%) and NPV of 61.9% (95% CI: 50.6% to 72.1%).**
- **Both scores performed better than peak systolic or mean velocity.**

TCD vs CTA/MRA

- CTA:
  - con: contrast, radiation;
  - pro: good visual
- MRA:
  - con: overintrepret %;
  - pro: non contrast OK
- TCD:
  - con: bone window, ?60-90%;
  - pro: bedside, real time monitoring

At Prince of Wales Hospital

- Population screening: TCD
- Stroke patients: TCD, MRA
- Evaluation for intervention: CTA + DSA

- Real time monitoring: TCD

Clinical Significance of TCD diagnosis?

Use of Transcranial Doppler Ultrasound to Predict Outcome in Patients With Intracranial Large-Artery Occlusive Disease

Ka Sing Wong, MD; Huan Li, MB; Yu Leung Chan, FRCR; Anil Ahuja, FRCR; Wynnie W.M. Lam, FRCR; Agatha Wong, RN; Richard Kay, MD

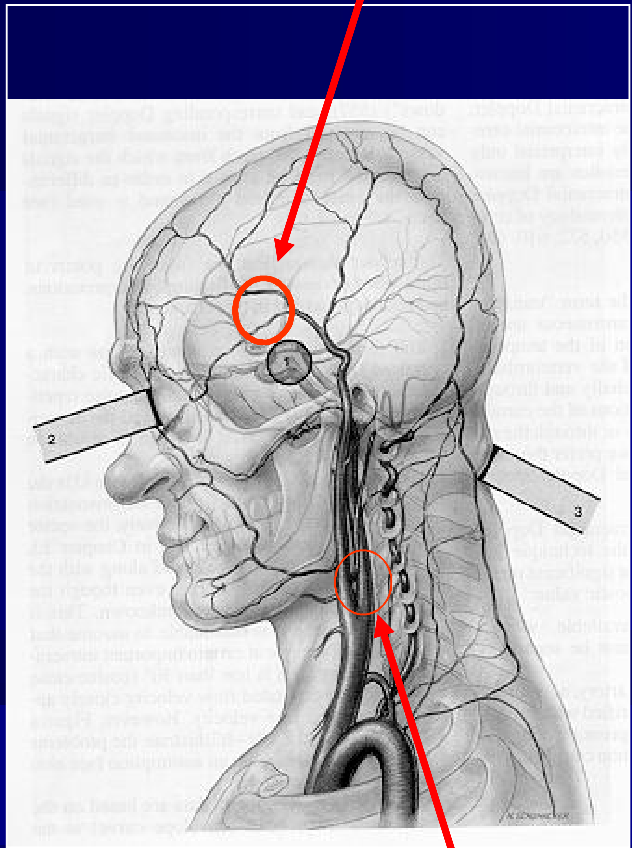
(*Stroke*. 2000;31:2641-2647.)

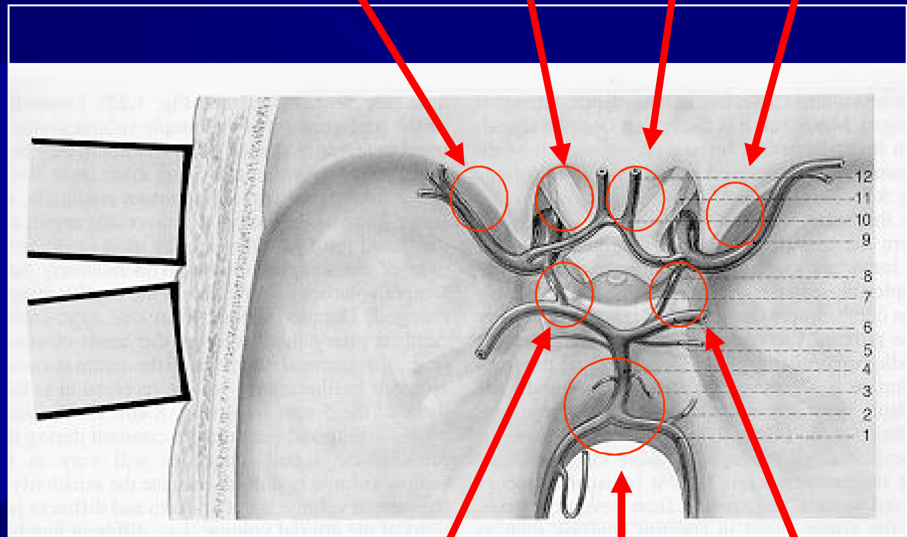
Acute Cerebral Ischemia

- 705 consecutive acute stroke/TIA patients within 12 months
- TCD, Duplex, CT scan
- Studied 11 arterial segments
- Six month follow-up: further vascular events (cerebral ischemia/acute coronary syndrome) or death

Stroke 2000 Nov

Arterial Segments Studied by Doppler



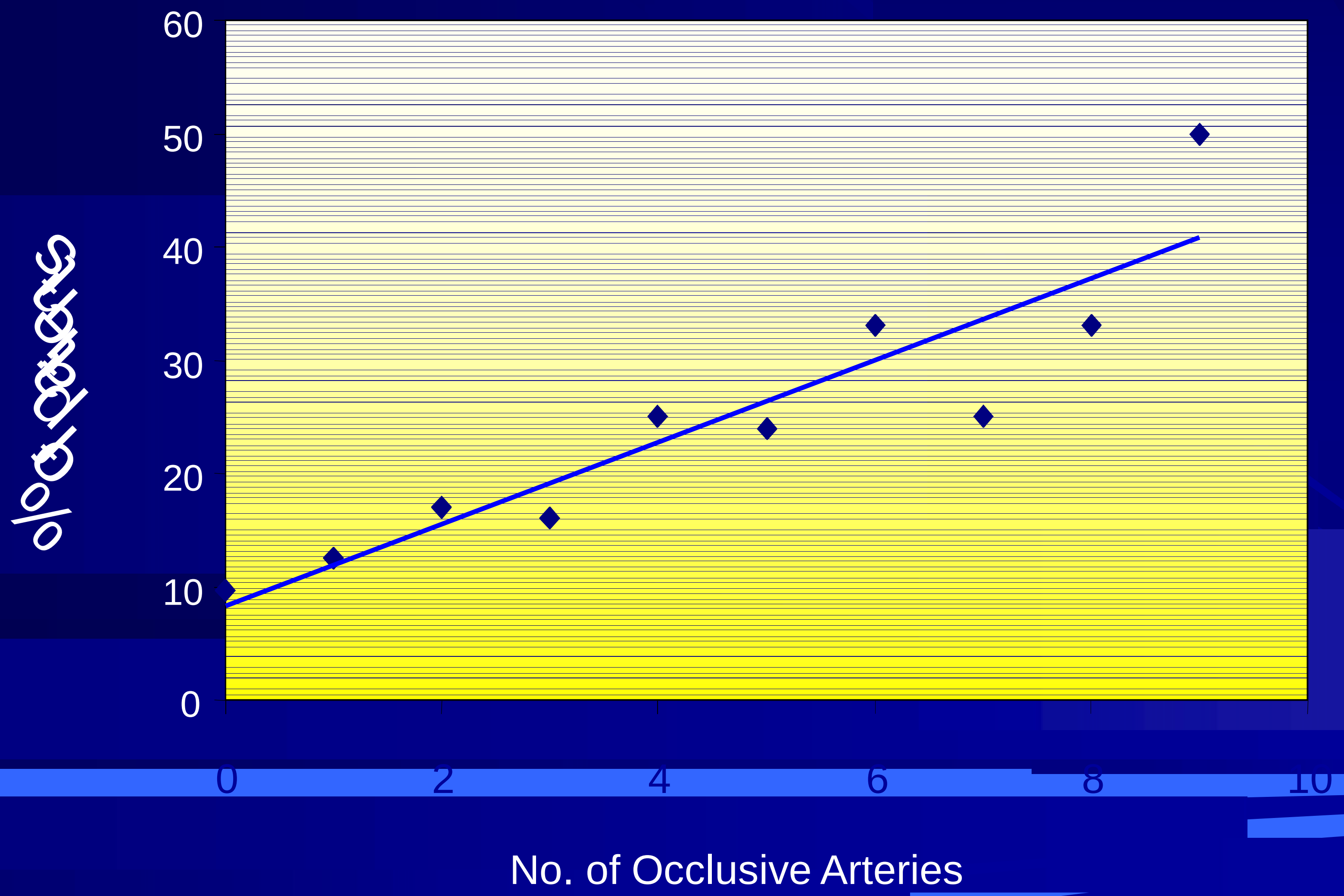


Total arterial segments = 11

Criteria

- The criteria for occlusive arteries were defined by the peak systolic flow velocity as follows:
  - 140 cm/s for the MCA,
  - 120 cm/s for the ACA,
  - 100 cm/s for the PCA and vertebrobasilar artery,
  - 120 cm/s for the siphon ICA
- Apart from the above velocity criteria, we took into account the age of patients, presence of turbulence or musical sound, and whether the abnormal velocity was segmental.

Further Vascular Event or Death



CONCLUSIONS

- TCD is a useful and widely available bedside tool to screen patients for intracranial occlusive disease
- It provides a comprehensive view of cerebral hemodynamics
- It supplements the results of MRA, CTA, and DSA
- Limitations
  - No temporal window
  - Operator/laboratory dependent

Subarachnid Hemorrhage

Subarachnoid hemorrhage

- Days 2-5 TCD can detect the development of vasospasm days before it can become clinically apparent, and this information can be used by intensivists to step up with hemodynamic management of these patients.
- Days 5-12 TCD can detect progression to the severe phase of spasm when development of the delayed ischemic deficit due to perfusion failure through the residual lumen is the greatest. This information can help planning interventions (angioplasty, nicardipine infusions).
- Days 12-end of ICU stay TCD can document spasm resolution after treatment or intervention, sustainability of vessel patency, and infrequent cases of late or rebound vasospasm development at the end of the second or into the third week after SAH.

Practice Standards for Transcranial Doppler (TCD) Ultrasound. Part II. Clinical Indications and Expected Outcomes. J Neuroimaging 2012;22:215-224.

TCD for SAH vasospasm

- The maximal sensitivity of TCD for detecting cerebral vasospasm is at 8 days after SAH onset, while its sensitivity for diagnosing delayed cerebral ischemia is lower (63%).
- TCD is highly specific (100%) for vertebral and basilar artery vasospasm when mean flow velocities are ?80 and ?85 cm/s, respectively.24 Another independent study showed that patients with very high basilar artery mean flow velocities (>115 cm/s) had a 50% chance of developing delayed brainstem ischemia, which in turn was associated with adverse functional outcome.
- Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology has recently stated that TCD is useful for the detection of vasospasm following spontaneous
- SAH.

- TCD vasospasm was defined as a flow velocity of at least 120 cm/s or peak flow velocity of more than 200 cm/s.

Angiographic Vasospasm Versus Cerebral Infarction as Outcome Measures After SAH

- A reduction of angiographic vasospasm did not correlate with an improvement on dichotomous GOS/mRS.
- In contrast, a reduction of cerebral infarction correlated with better neurological outcomes.

- Conclusion: Future clinical trials may use cerebral infarction and functional outcome as main outcome measures to investigate the true impact of an intervention, assuming that the intervention targets cerebral infarction and hereby improves outcome.

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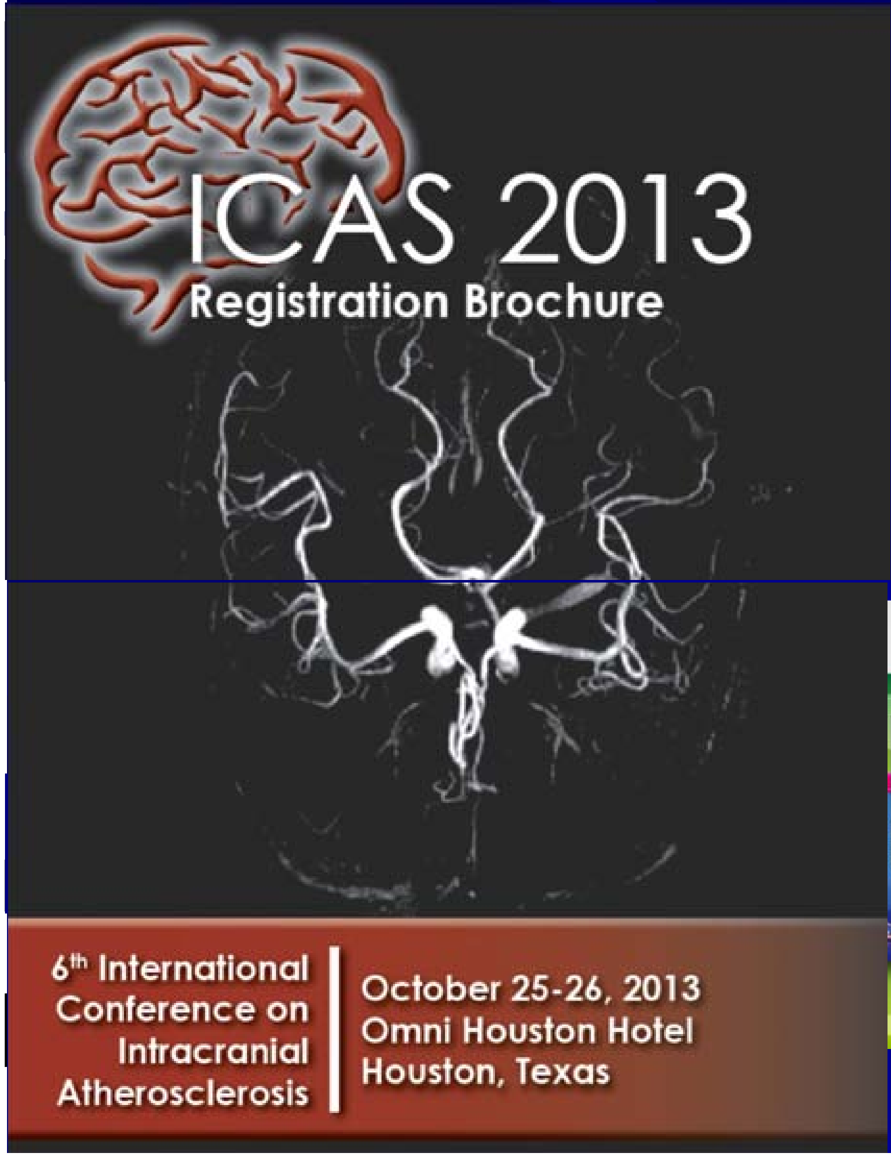
Thank You



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