TRANS CRANIAL DOPPLER

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Transcranial Doppler

- 1982, Aaslid and colleagues introduced TCD as a non-invasive technique for monitoring blood flow velocity in basal cerebral arteries in patients with SAH
- Now increasingly used in intensive care units and anesthesia for research and clinical practice

Doppler Effect

- 1842, Christian Doppler - frequency shift of reflected and scattered signals that occurs whenever there is relative motion between the emitter and the object or interface reflecting the sound

Principles

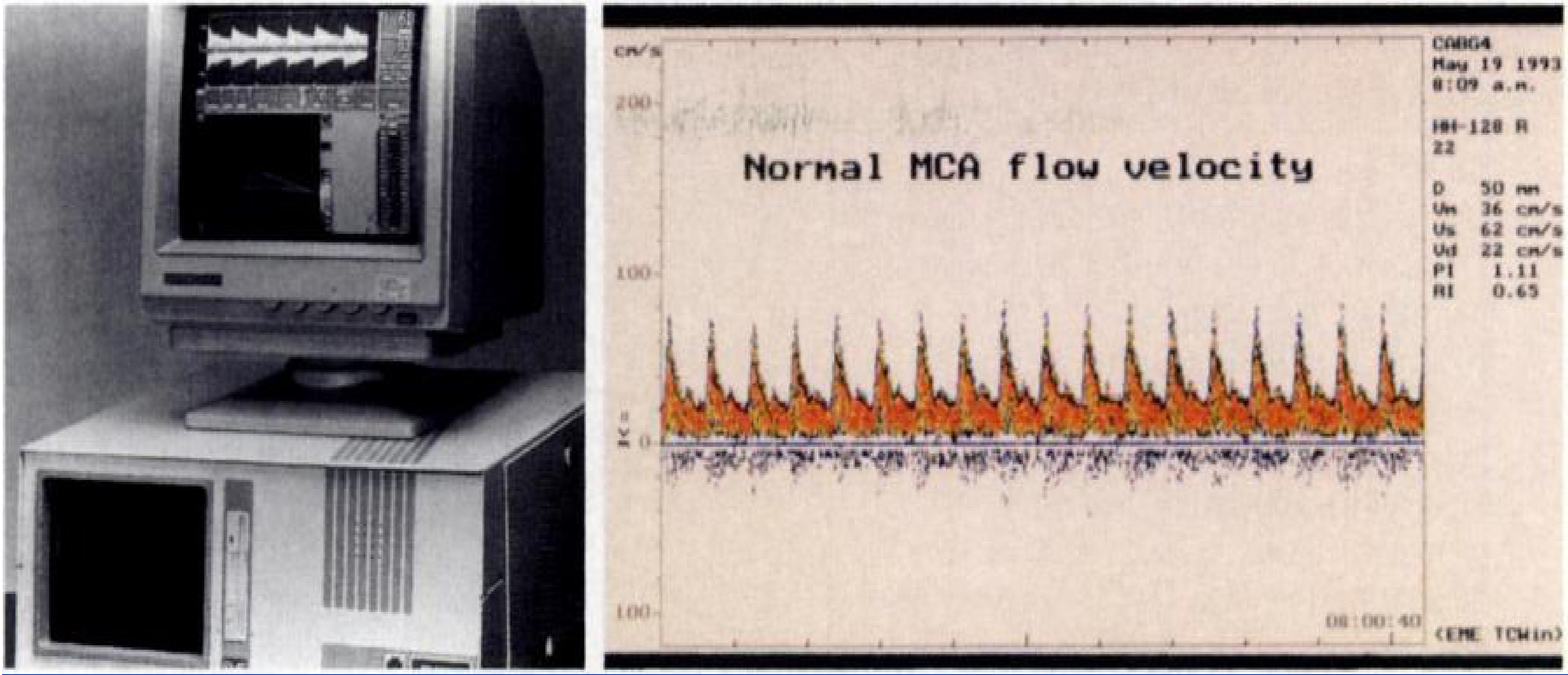
- uses a handheld, directional, microprocessor-controlled, low-frequency (2-MHz), pulsed Doppler transducer to measure the velocity and pulsatility of blood flow within the arteries of the circle of Willis and vertebrobasilar system
- noninvasive, nonionizing, portable, inexpensive, safe for serial or prolonged studies

- Based on detection of frequency shifts from insonated RBC moving through a small preselected arterial spatial region (sample vol)
- Sample volume is determined by lateral focussing of the transducer, duration of transmitted sound burst at a specific pulse repitition rate (PRF) and duration of the range gate opening (Ts)

History

- 1979, Nornes described the intraoperative pulsed doppler sonographic method to study cerebral hemodynamics
- 1982, Aaslid et al introduced the 2 MHz pulsed doppler device that enabled the noninvasive transcranial measurement of blood flow velocity in large intracranial basal vessels

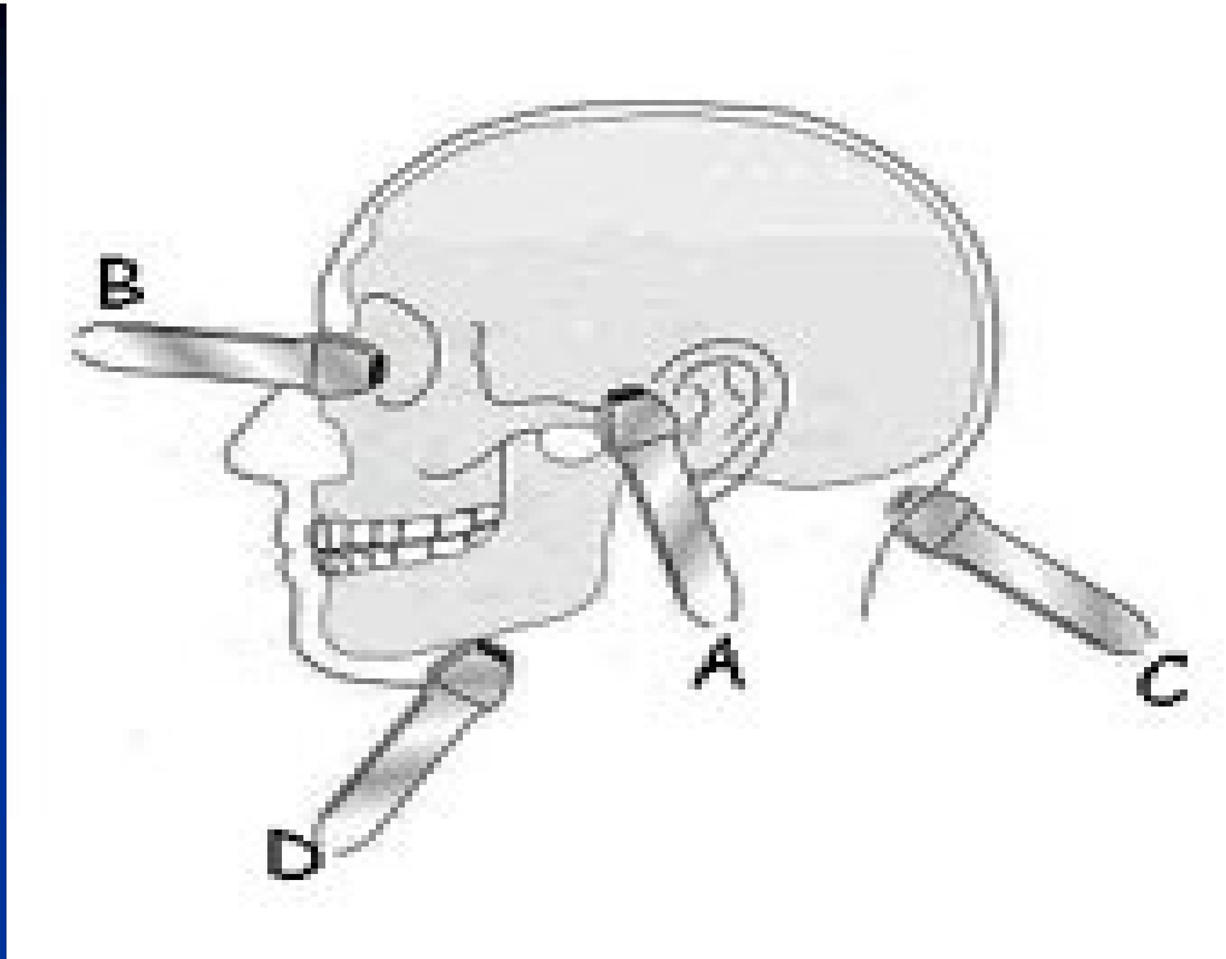
- 1986, Eden Medical Electonics developed the Trans-scan, device capable of three dimensional, multiprojectioal flow mapping, colour coded for flow direction and velocity
- 1988, EME introduced the TC20005 scanner, TCD with advanced post-processing and display capabilities
- Recent developments- introduction of intravascular sonographic contrast agents, multi-channel transcranial doppler



Doppler equipment with its display format (profile of a normal right middle cerebral artery [MCAI). (a) Photograph shows an EME TC2000S, a more sophisticated device with advanced postprocessing and color display capability.
(b) Color-coded spectral analysis is provided, along with calculation and display of peak systolic and diastolic velocities *(Vı* and I'), mean velocity *(Vrn)ı* and pulsatility and resistive indexes (*P1* and *RI).*

Examination Technique

- Can be performed in any patient- awake or comatose
- Four naturally occurring cranial windows
  - Transtemporal- 3 windows
  - Transorbital
  - Transforaminal
  - Submandibular
  - In addition- open fontanelle, burr holes



A. Transtemporal, B. Transorbital
C. Transforaminal, D. Submandibular

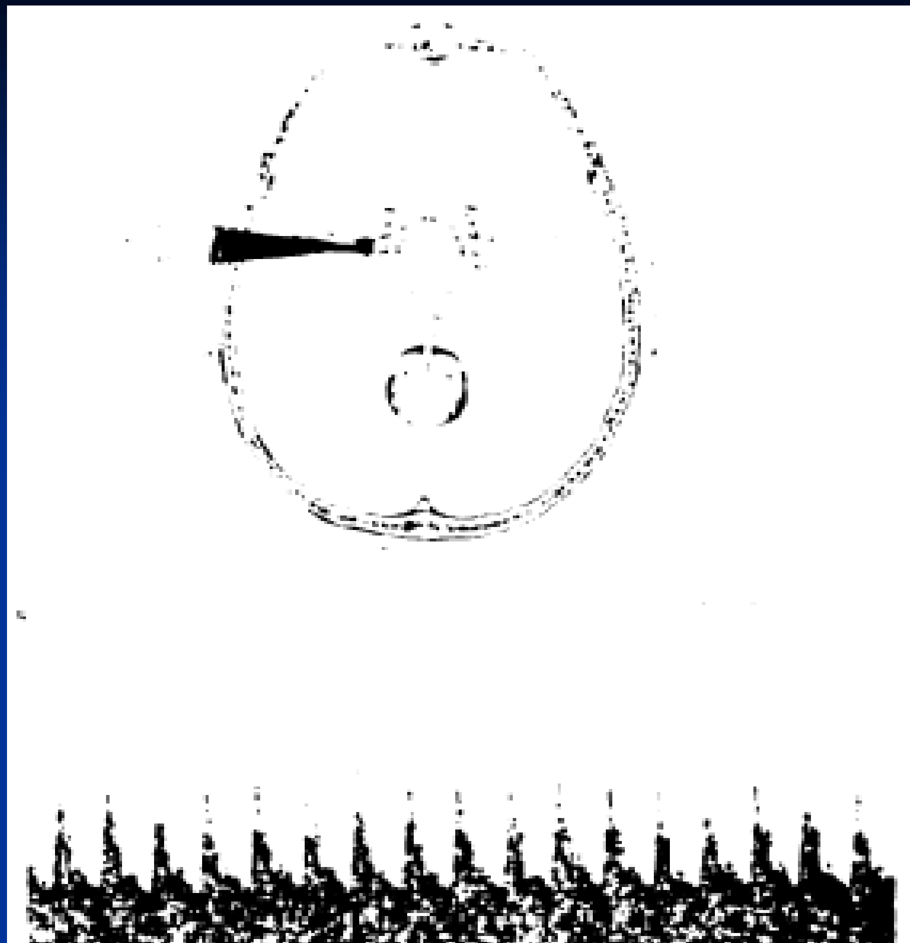
- Criteria for Vessel Identification
- I . Cranial window used
- 2. Depth (mm) of sample volume
- 3. Direction of flow (toward or away from transducer, bidirectional)
- 4. Distance (mm) oven which vessel can be traced without branching
- 5. Relationship to TICA/MCA/ACA junction
- 6. Angle of transducer in relationship to patient's head and cranial windows
- 7. Relative flow velocity (MCA > ACA > PCA = BA = VA)
- 8. Response to common carotid artery compression

Angle of insonation

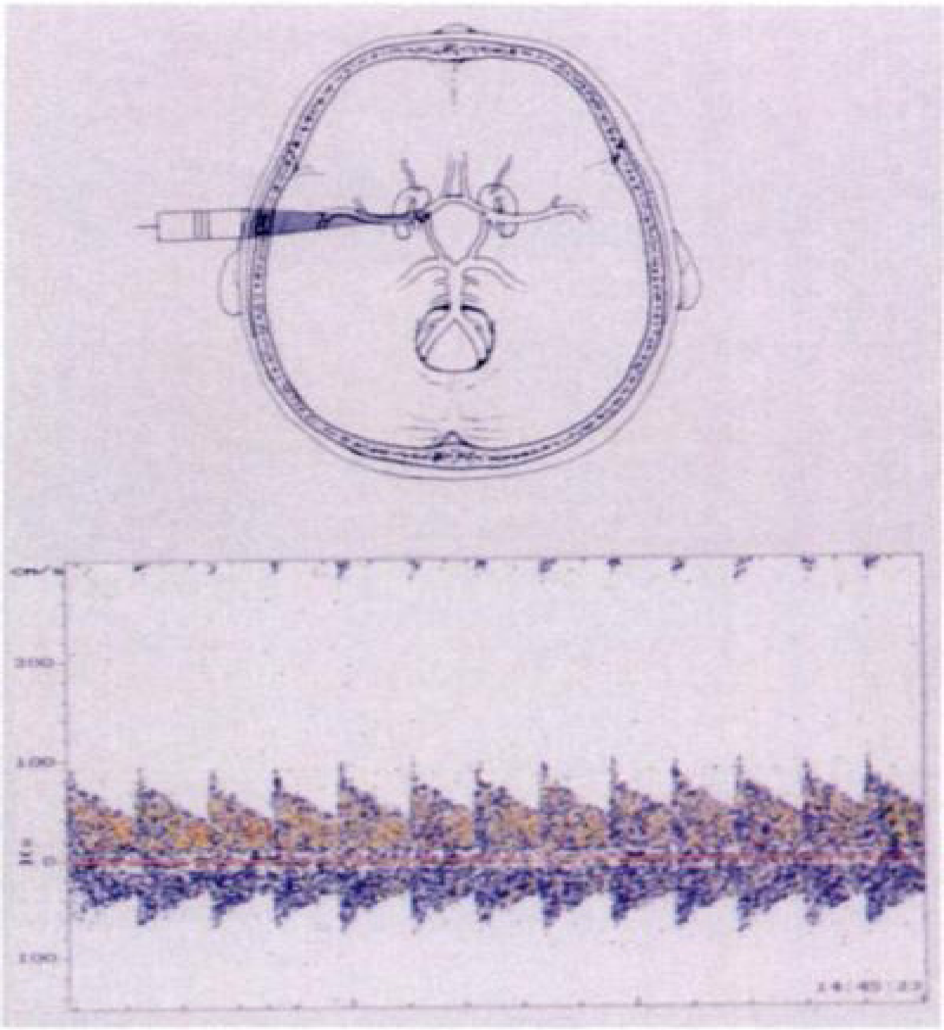
- Angle between the ultrasound beam and the vessel being recorded from
- Important to measure true TCD velocity
- Observed velocity = True velocity X cosine of angle of insonation

Vessel Identification Criterion

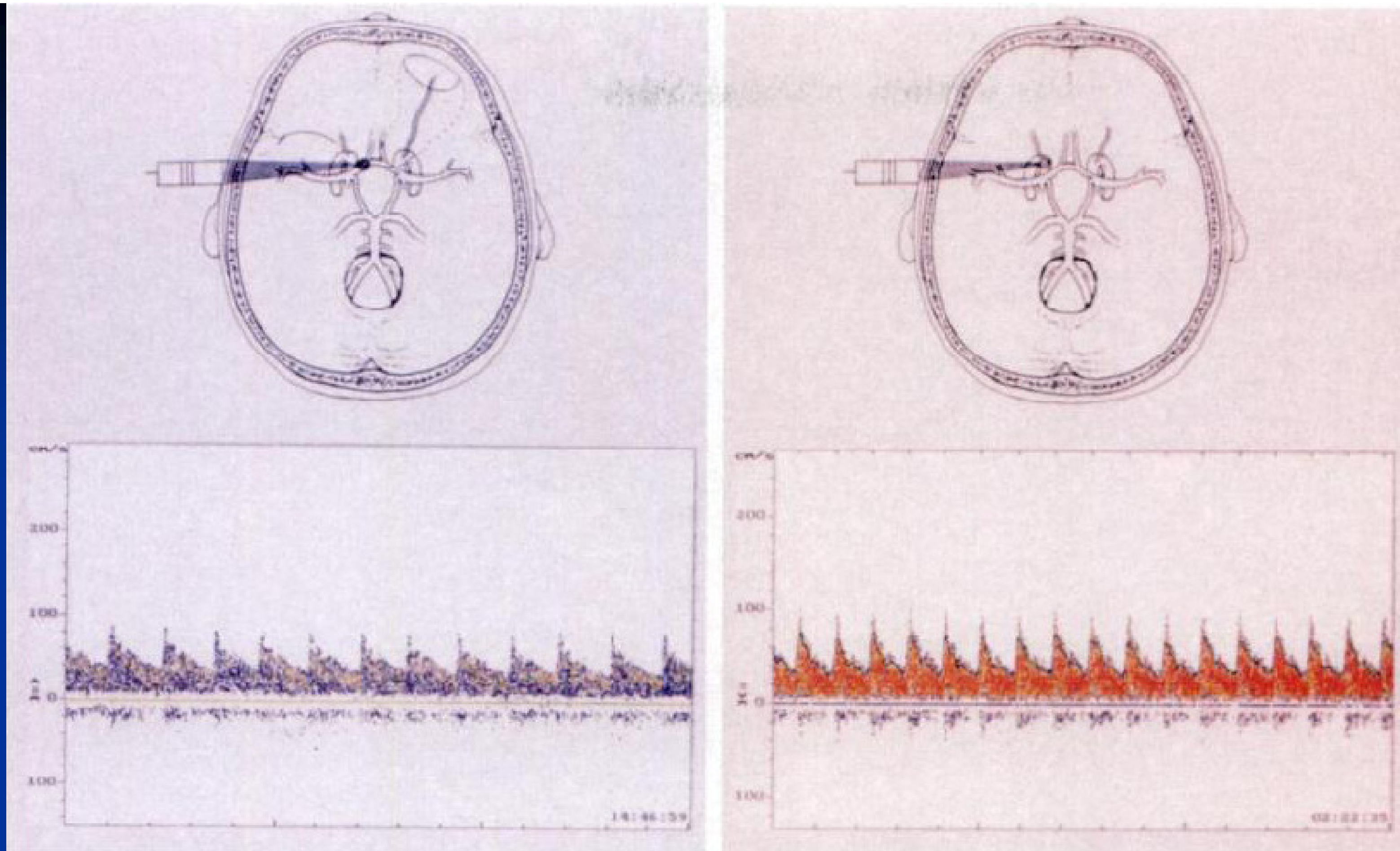
Vessel	Window	Depth	Direction	Velocity
MCA	TT	45-65	Toward	46-86
ICA Bifur	TT	60-65	Bidirectional	
ACA	TT	60-75	Away	41-76
PCA 1	TT	60-75	Toward	33-64
PCA 2	TT	60-75	Away	33-64
Ophthalmic	TO	45-60	Toward	21-49
ICA (supra-clinoid)	TO	60-75	Away	50-60
Vertebral	TF	65-85	Away	27-55
Basilar	TF	90-120	Away	30-57



Middle cerebral artery (Ml). Diagram depicts the transducer position at the anterior transtemporal window. The transcranial Doppler spectral display obtained at a sample volume depth of 45-65 mm shows the normal blood flow velocity of 46-86 cm/sec. The flow is toward the transducer.

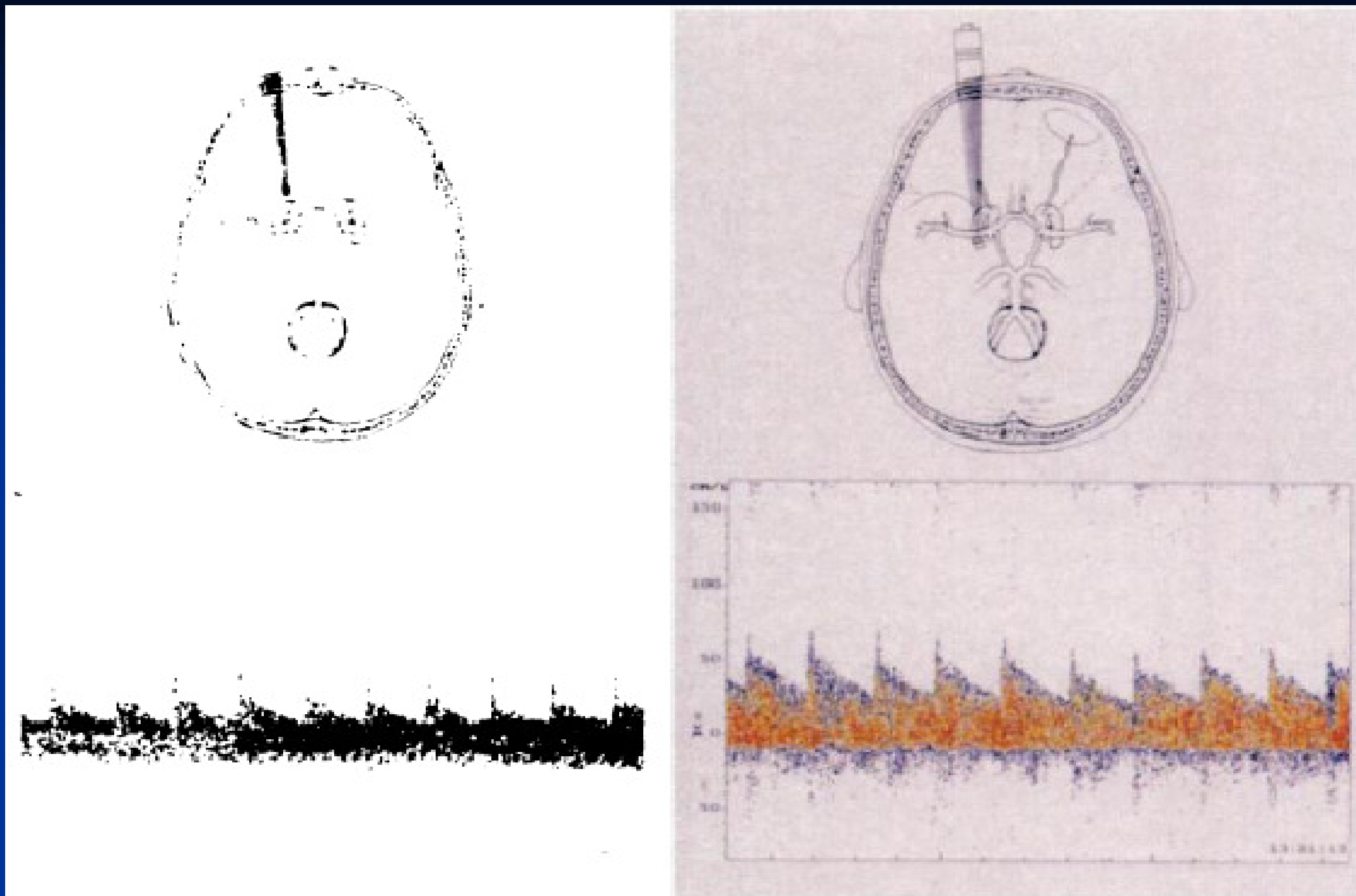


Bifurcation of the middle and anterior cerebral arteries. Diagram depicts the transducer position at the anterior transtemporal window. The transcranial Doppler spectral display obtained at a sample volume depth of 60-65 mm shows the normally bidirectional flow



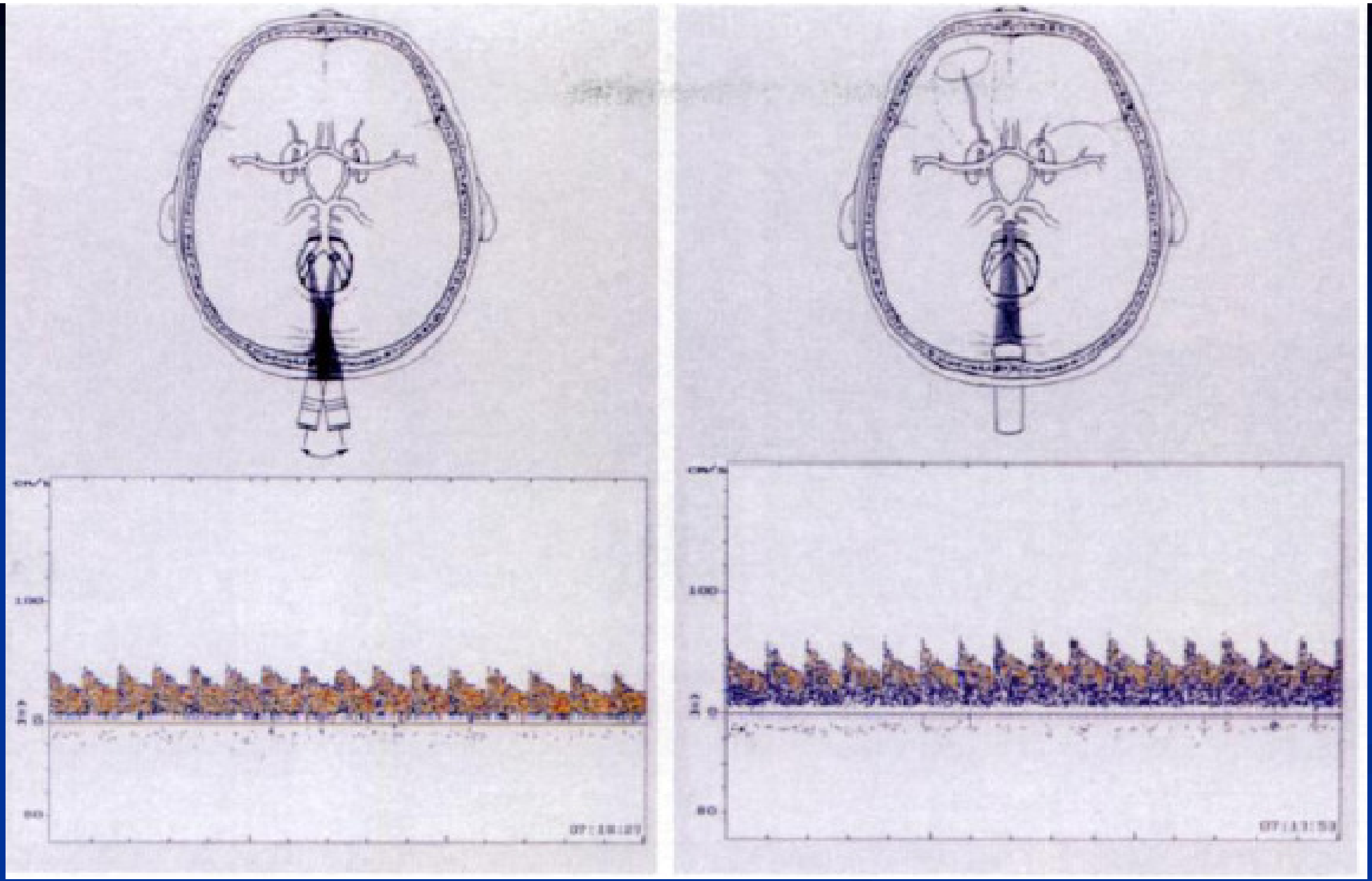
Anterior cerebral artery (Al). Diagram depicts the transducer position at the anterior transtemporal window. The transcranial Doppler spectral display obtained at a sample volume depth of 60-75 mm shows the normal blood flow velocity of 4 1-76 cm/sec. The flow is away from the transducer.

Terminal internal carotid artery. Diagram depicts the transducer position at the middle transtemponal window. The transcranial Doppler spectral display obtained at a sample volume depth of 60-65 mm shows the normal blood flow velocity of 30-48 cm/sec. The flow is toward the transducer.



Ophthalmic artery. Diagram depicts the transducer position at the transorbitab window. The transcranial Doppler spectral display obtained at a sample volume depth of 45-60 mm shows the normal blood flow velocity (2 1 -49 cm/see). The flow is toward the transducer.

Carotid siphon. Diagram depicts the transducer position at the transorbital window. The transcranial Doppler spectral display obtained at a sample volume depth of 60-75 mm shows the normal bloodflow velocity of 50-60 cm/sec. The



Vertebral artery. Diagram depicts the transducer position at the transforaminal (suboccipital) window. The transcranial Doppler spectral display obtained at a sample volume depth of 65-85 mm shows the normal blood flow velocity of 27-55 cm/sec. The flow is away from the transducer.

Basilar artery. Diagram depicts the transducer position at the transforaminal (suboccipital) window. The transcranial Doppler spectral display obtained at a sample volume depth of 90- 1 20 mm shows the normal blood flow velocity of 30-57 cm/sec. The flow is away from the transducer.

Pulsatility

- Described by the shape of the spectral waveform
- Relates to the peripheral resistance of the cerebral tissue supplied by the insonated vessel and the input signal
- Normal Vs> Vd
- High pulsatilty Vs>>Vd
- Damped pulsatility Vd > 50% of Vs

Pulsatility Index

- Gosling Equation

  PI = Vs – Vd/ Vm
- Normal = 0.8- 1.2
- Increased > 1.2, seen in Increased ICP, hypocapnia, aortic insufficiency, bradycardia
- Decreased < 0.8, seen in vessel supplying AVM due to decreased peripheral vascular resistance, downstream high grade stenosis

Effect of internal carotid stenosis on cerebral hemodynamies. Transeranial Doppler spectrum demonstrates decreased blood flow velocity (estimated; mean velocity = 36 cm/see) with decreased pulsatility in the left middle cerebral artery *(MCA)*

Physiologic factors affecting TCD

- Age
- Sex
- Hematocrit
- Temperature
- Hypoglycemia
- Blood CO_2 level
- Cardiac Output
- Brain Activity

Use in Neurosurgery and Anesthesia

- Intracranial and extracranial Vascular Abnormalities
  - Intracranial
    - SAH and Vasospasm
    - Head Injury
    - Arteriovenous Malformation
    - Arterial stenosis and Occlusion
    - Detection of aneurysm
    - Brain Death
  - Extra cranial
    - Subclavian steal Syndrome
    - Carotid Stenosis
    - Positional Vertebral artery Occlusion

Use in Neurosurgery and Anesthesia

- Intraoperative and procedural Monitoring
  - Carotid Endarterectomy
    - For cross-clamp Hypoperfusion
    - Detection of emboli
    - Postoperative hyperperfusion
    - Postoperative occlusion
  - Cardiopulmonary Bypass

SAH and Vasospasm

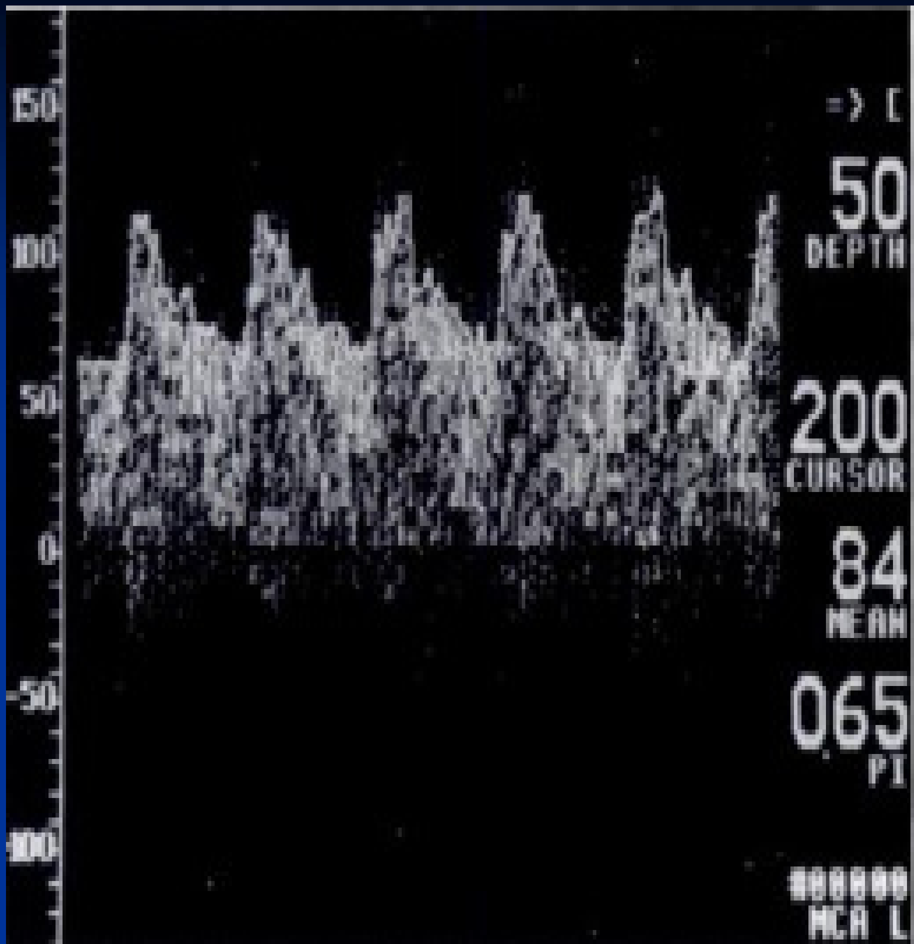
- Most accurate in MCA
- Velocity > 120 cm/s = Vasospasm

  > 200 cm/s = Severe Vasospasm
- Velocity Increase > 50 cm/S over 24 hour period – high risk for DIND
- D/D vasospasm and Hyperemia
- Lindegaard Ratio

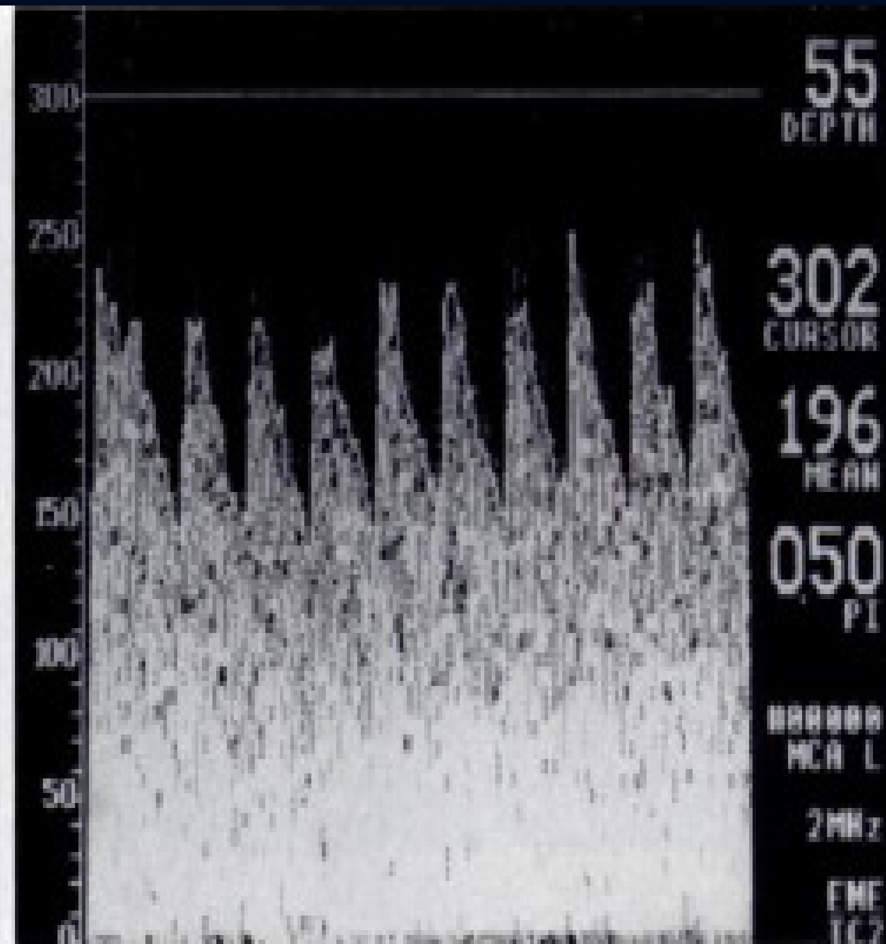
  V_{MCA}/V_{ICA} (1.7 ± 0.4)

  > 3 = vasospasm

- Monitoring response to Tripple H therapy, Endovascular therapy
- Detection of Intracranial Aneurysm – introduction of trans-cranial colour coded sonography
- Peroperatively can be used for assessing the vasospasm, patency of vessels, residual aneurysm



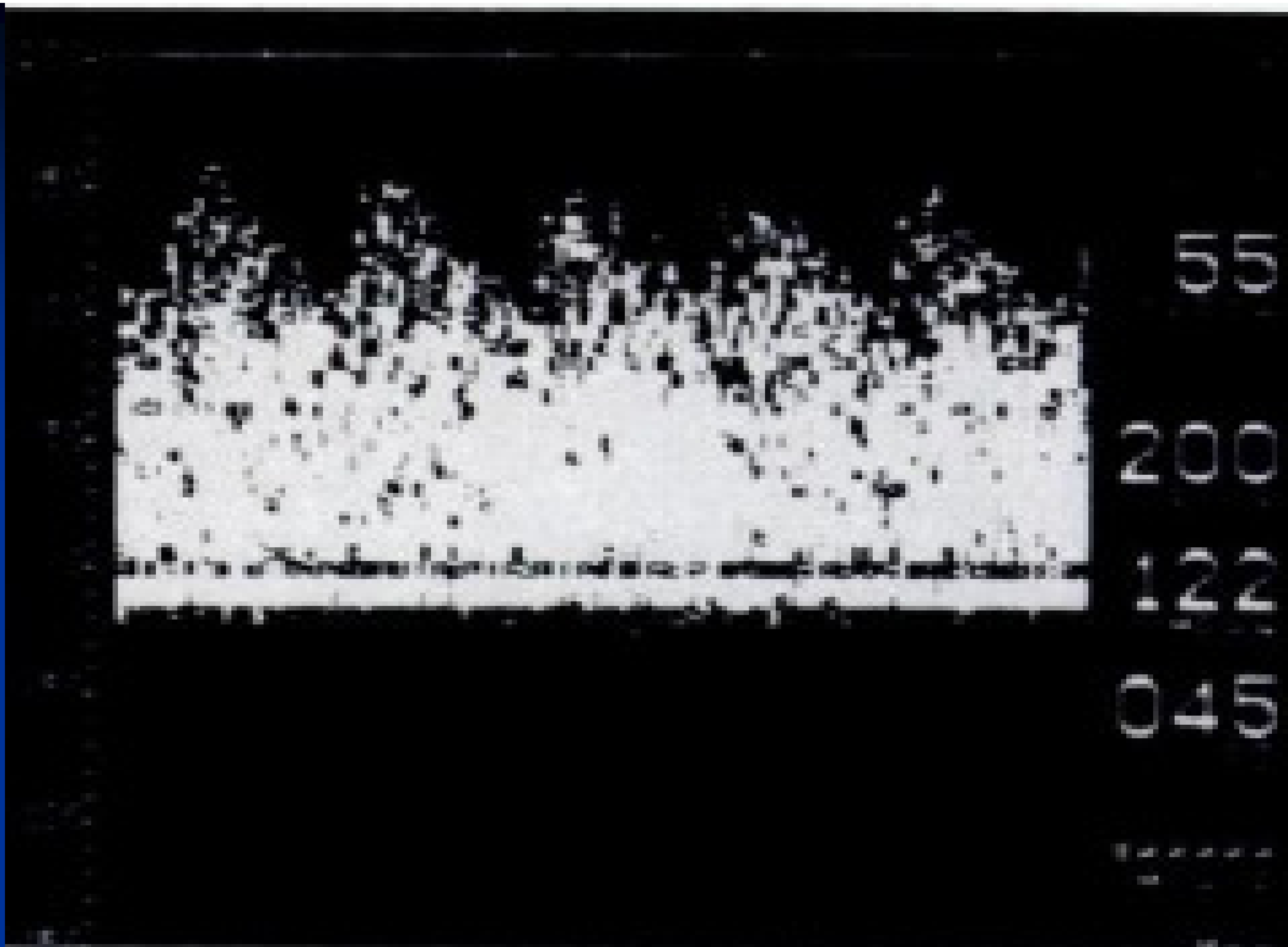
2 days after SAH



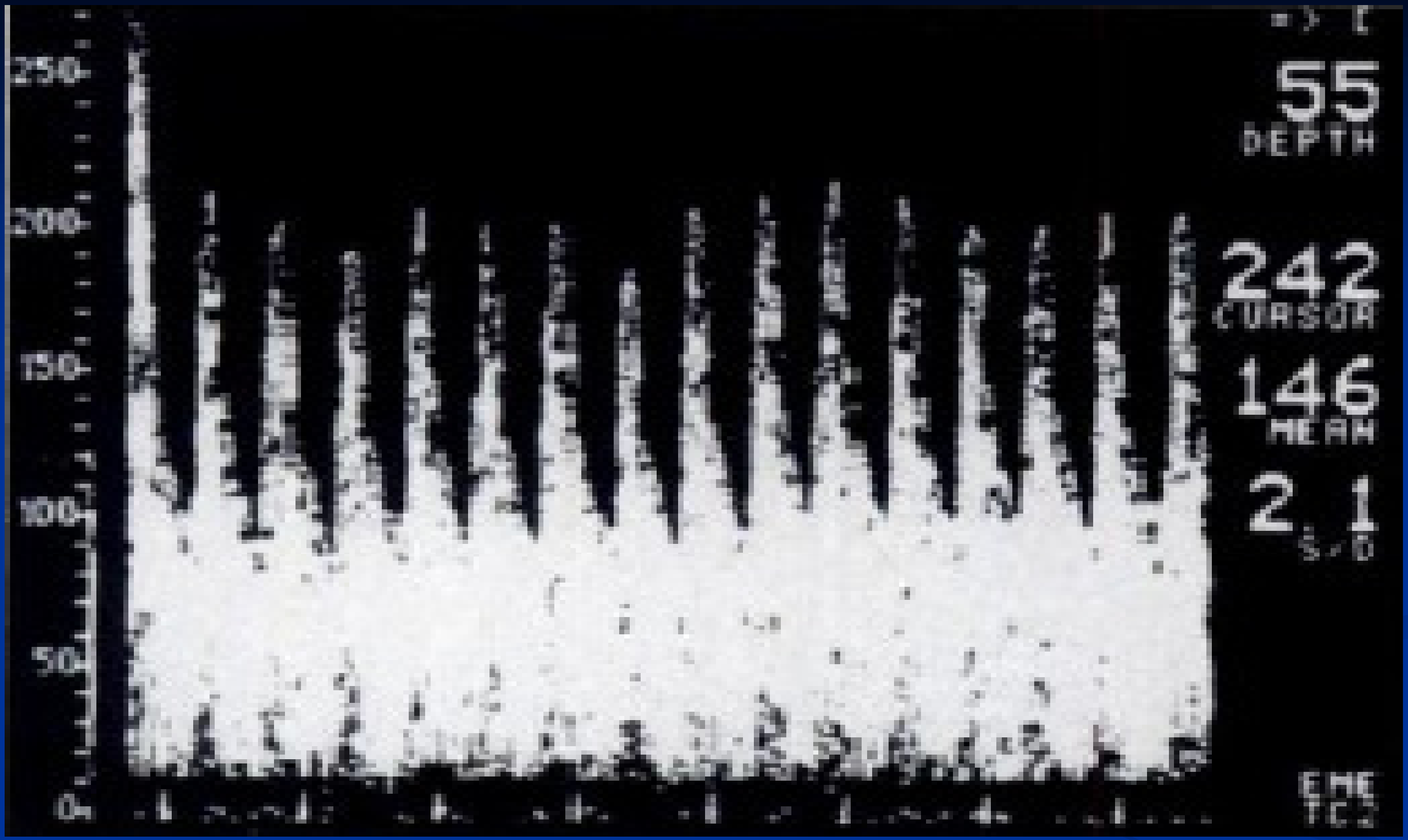
11 days after SAH

Head Injury

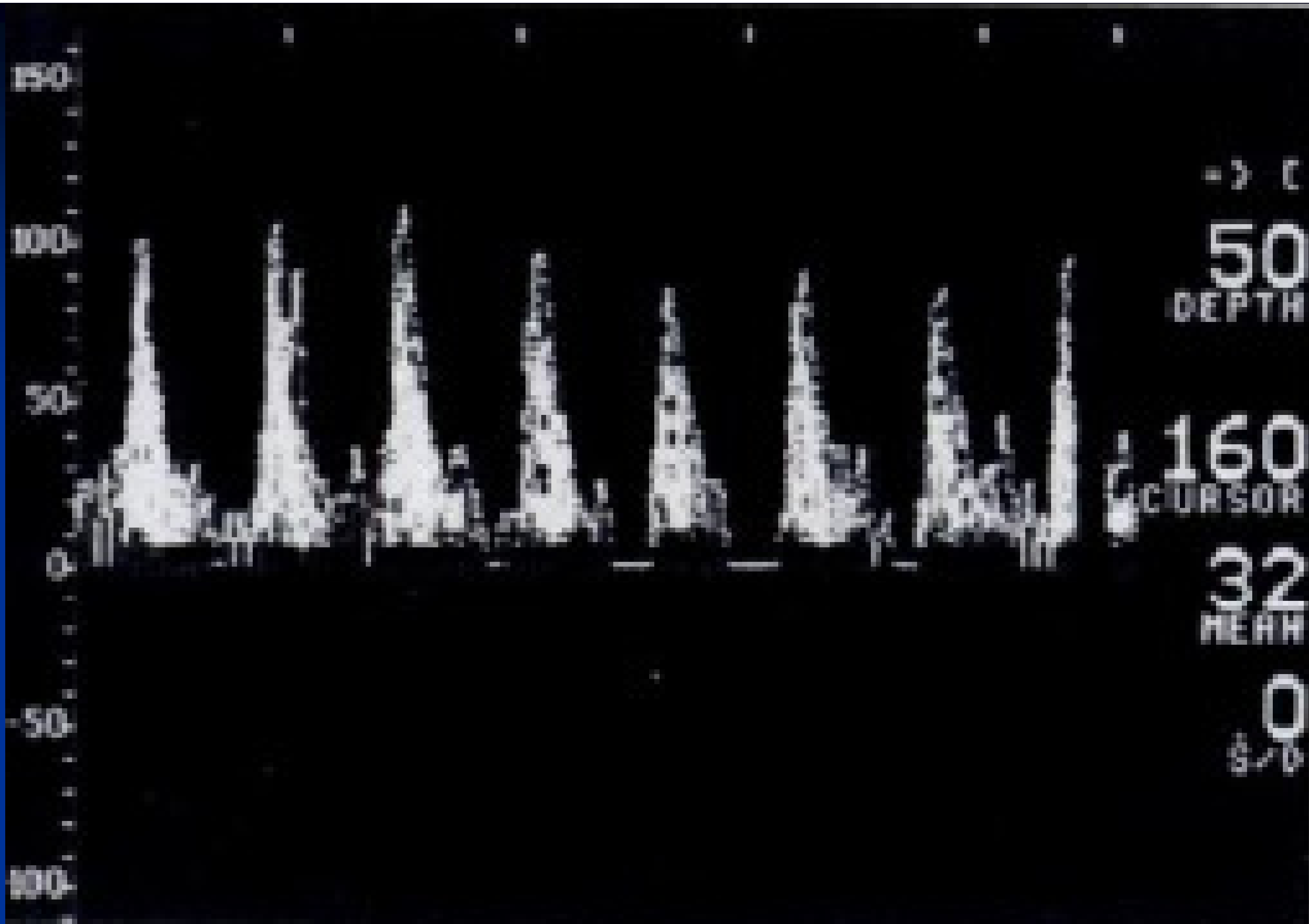
- Blood flow velocity from relative flow changes- Vasospasm/ Hyperemia
- CO2 reactivity
- Cerebral Autoregulation
  - Static autoregulation
  - Dynamic autoregulation
- Post-traumatic Vasospasm
- Vascular Dissection



Head Trauma (a) Vasospasm
Lindeegaard Ratio 3.2



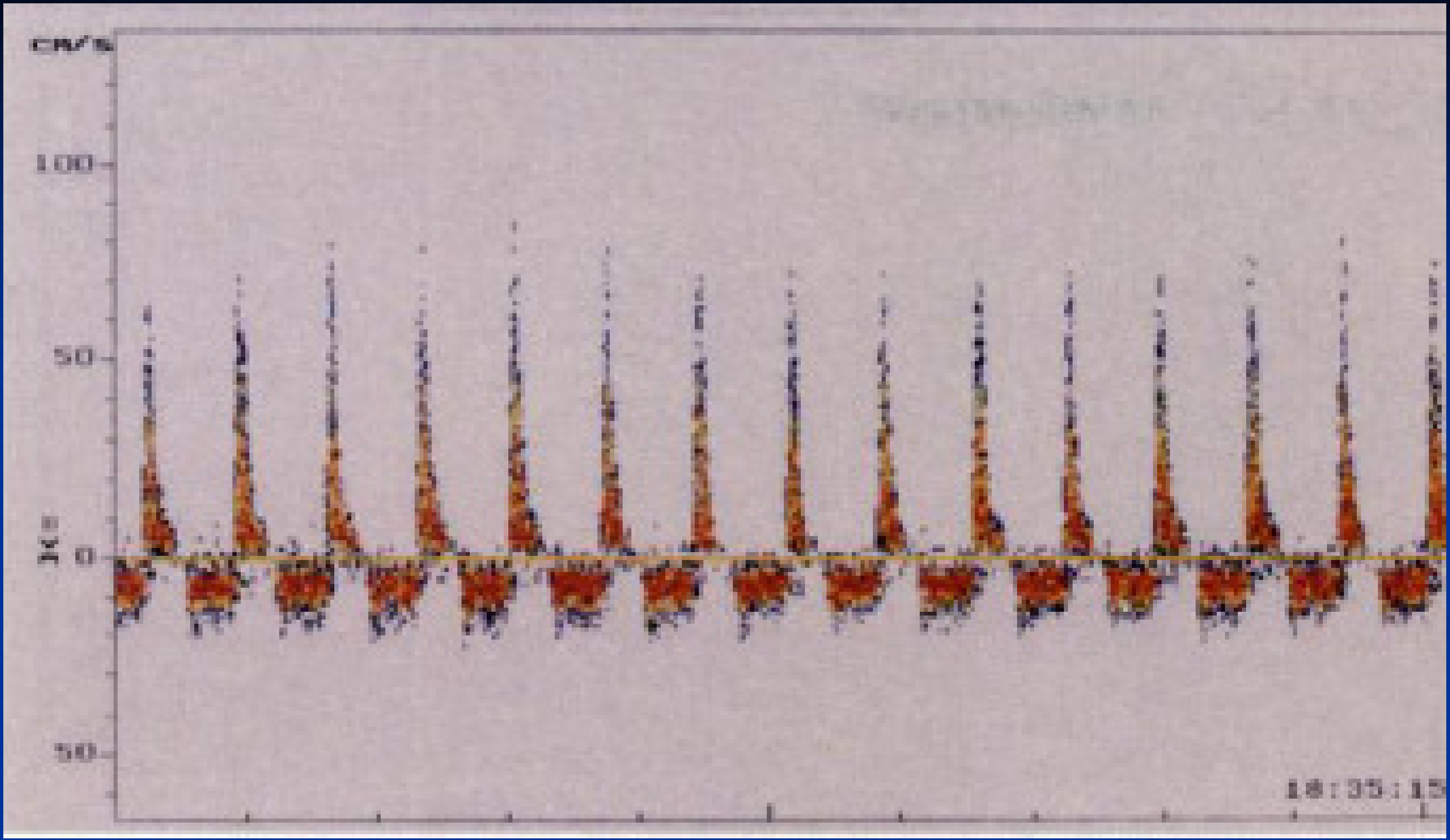
Head Injury (B) Hyperemic Response due to defective autoregulation
Lindeegaard Ratio- 2.0



Head Injury (c) Increased intracranial pressure

Brain death

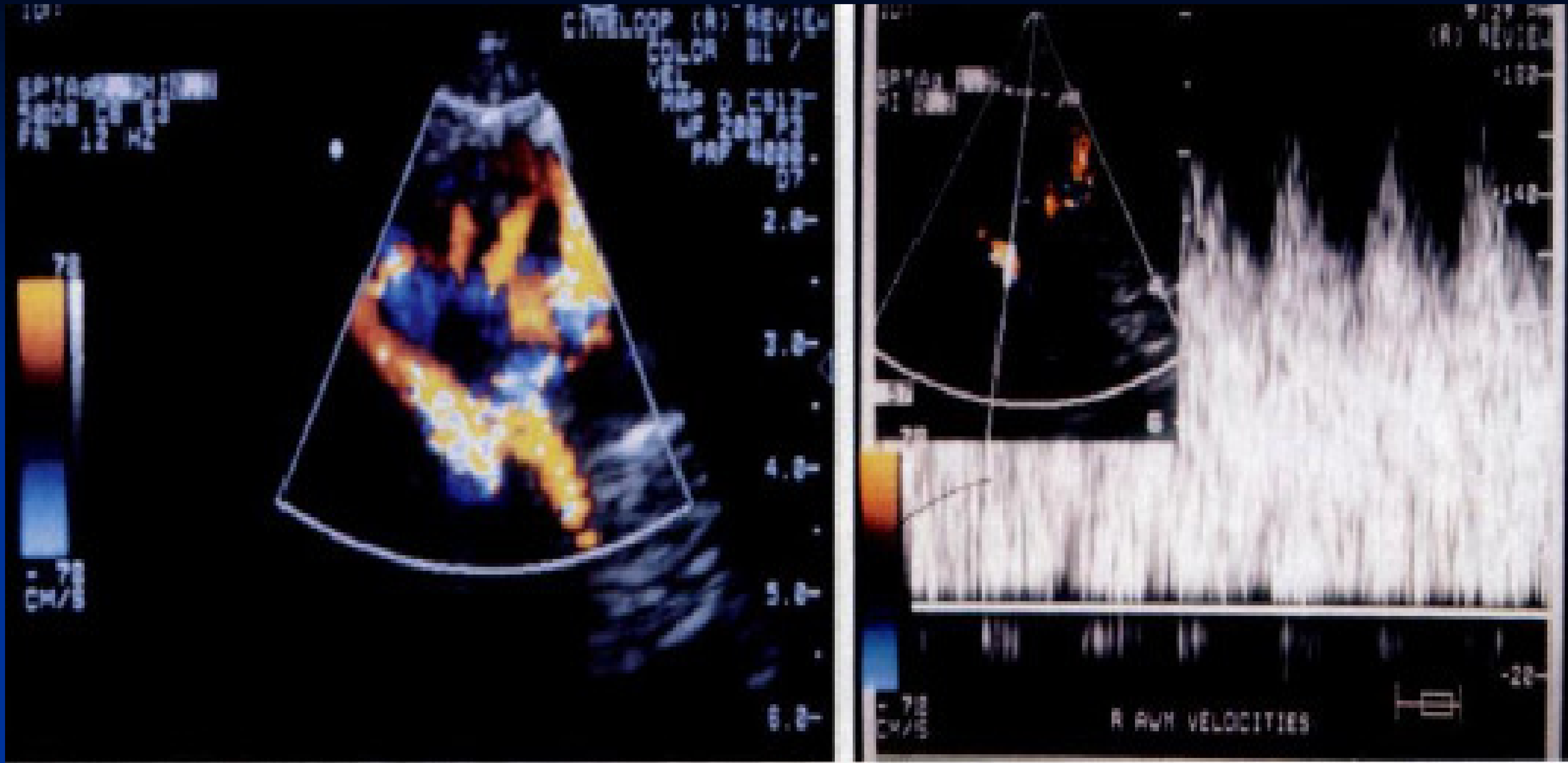
- False positive
  - Cerebral circulatory arrest can be transient
  - Residual brainstem circulation
  - Abnormally low diastolic pressure; IABP
- False Negative
  - Complete destruction of brainstem with preserved supratentorial flow



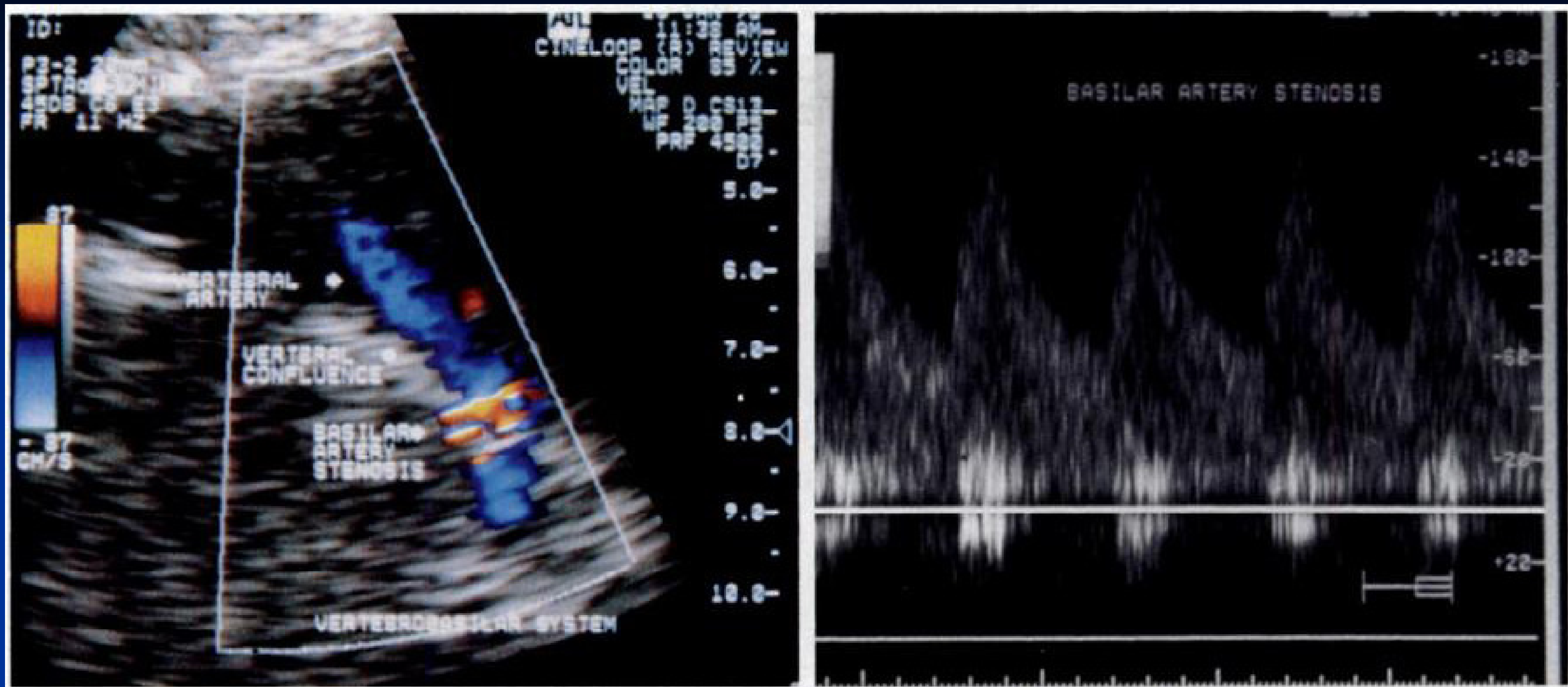
Brain Death
TCD- to and fro pattern of blood flow- cerebral circulatory arrest

Arteriovenous Malformation

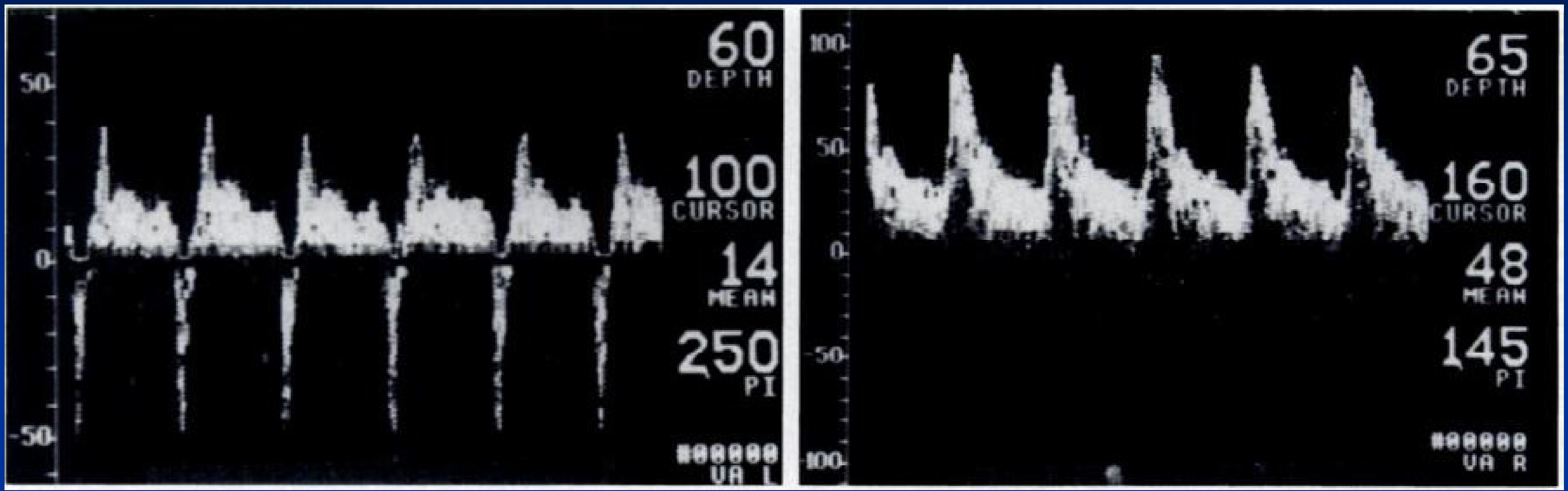
- High velocity in feeding arteries
- Low pulsatility index s/o decreased peripheral vascular resistance
- Defective autoregulation
- Intraoperative use to detect residual aneurysm during surgery or neuroendovascular procedures



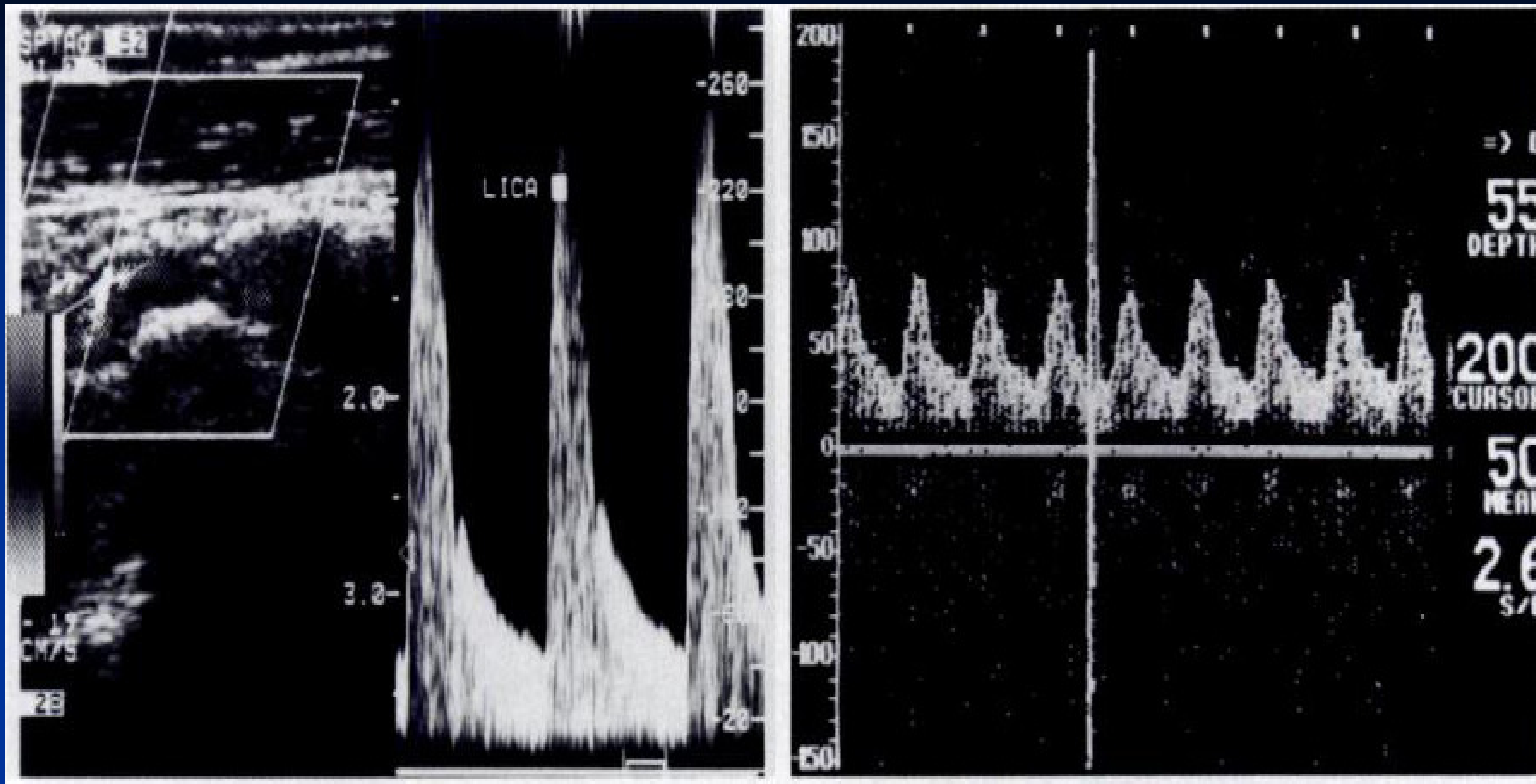
Right frontal arteriovenous malformation.
(a) Color transcnanial Doppler image demonstrates increased blood flow velocity (estimated) in multiple channels of the arteriovenous malformation. (b) Color transcranial Doppler spectral analysis of a feeding artery demonstrates a high blood flow velocity (estimated; mean velocity = 140 cm/see) with a damped waveform, indicative of low pulsatility.



Basilar artery stenosis. (a) Colon transcranial Doppler image demonstrates a focus of abnormal blood flow in the middle portion of the basilar artery, a finding suggestive of stenosis. (b) Transcranial Doppler waveform of this portion of the basilar artery demonstrates focally increased blood flow velocity (estimated; mean velocity = 105 cm/see).

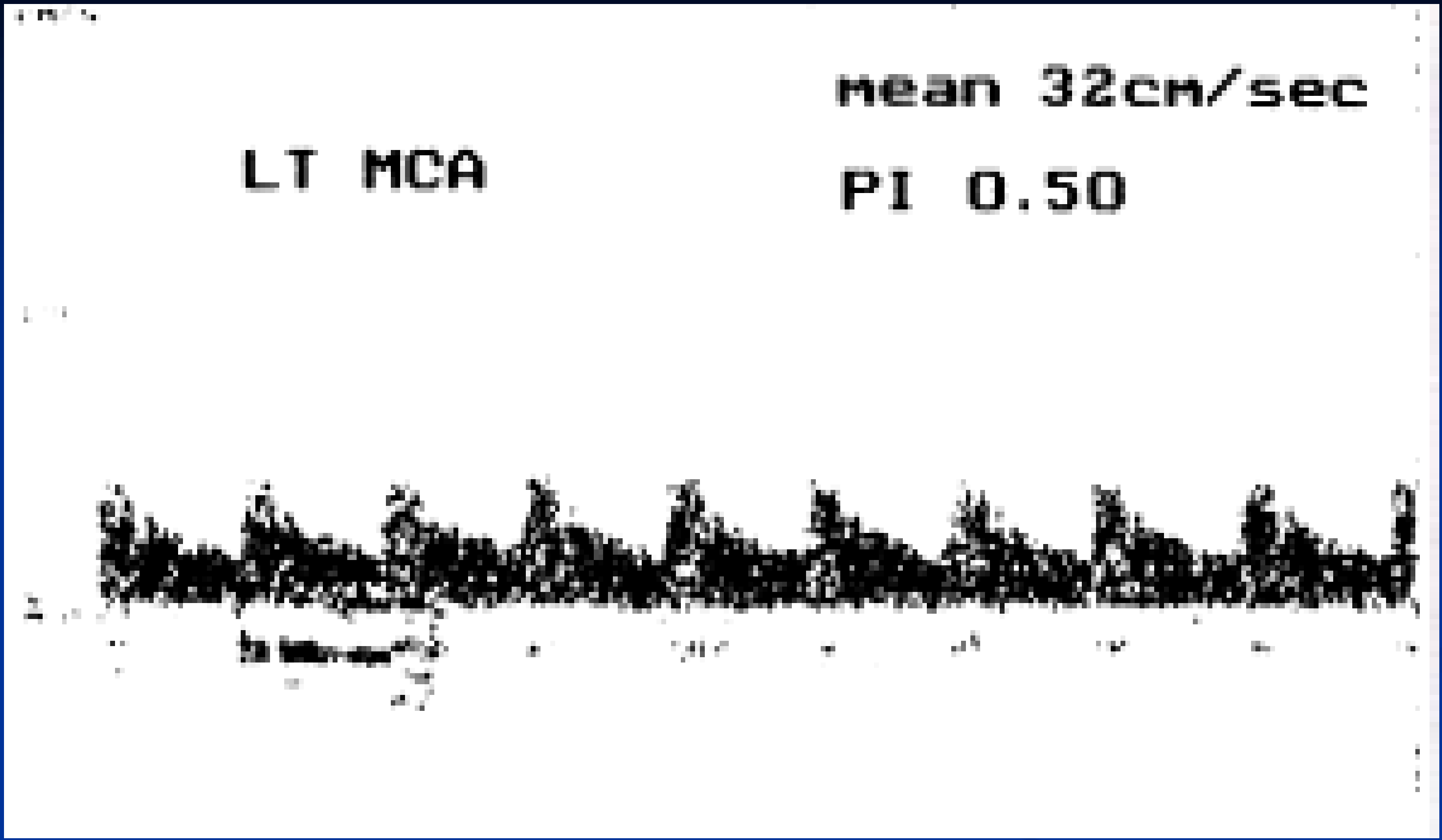


Subclavian steal syndrome. (a) Transcranial Doppler waveform demonstrates intermittent reversal of flow in the left vertebral artery *(VA L),* suggestive of an incomplete steal. *P1* = pulsatility index. (b) Transcranial Doppler waveform of the normal right vertebral artery *(VA R)* is shown for comparison.



Effect of internal carotid artery stenosis on cerebral hemodynamics. (a) Duplex sonogram demonstrates a hemodynamically significant stenosis (79%-95% narrowing) in the proximal left internal carotid artery *(LICA)* The peak systolic velocity is greater than 125 cm/sec with marked spectral broadening.

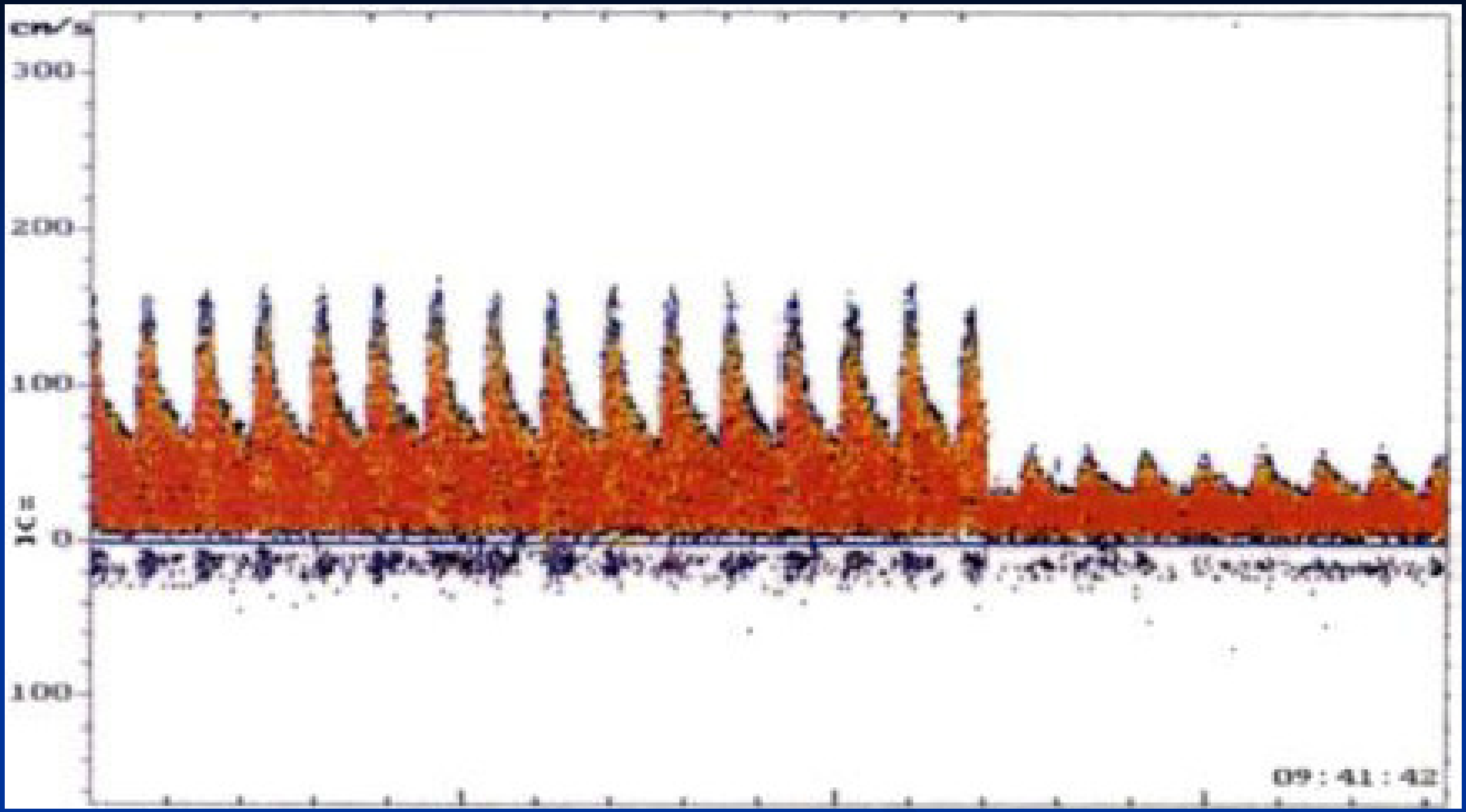
(b) **Transcranial Doppler waveform obtained during surgery demonstrates an embolus** in the left middle cerebral artery, suggestive of plaque ulceration.



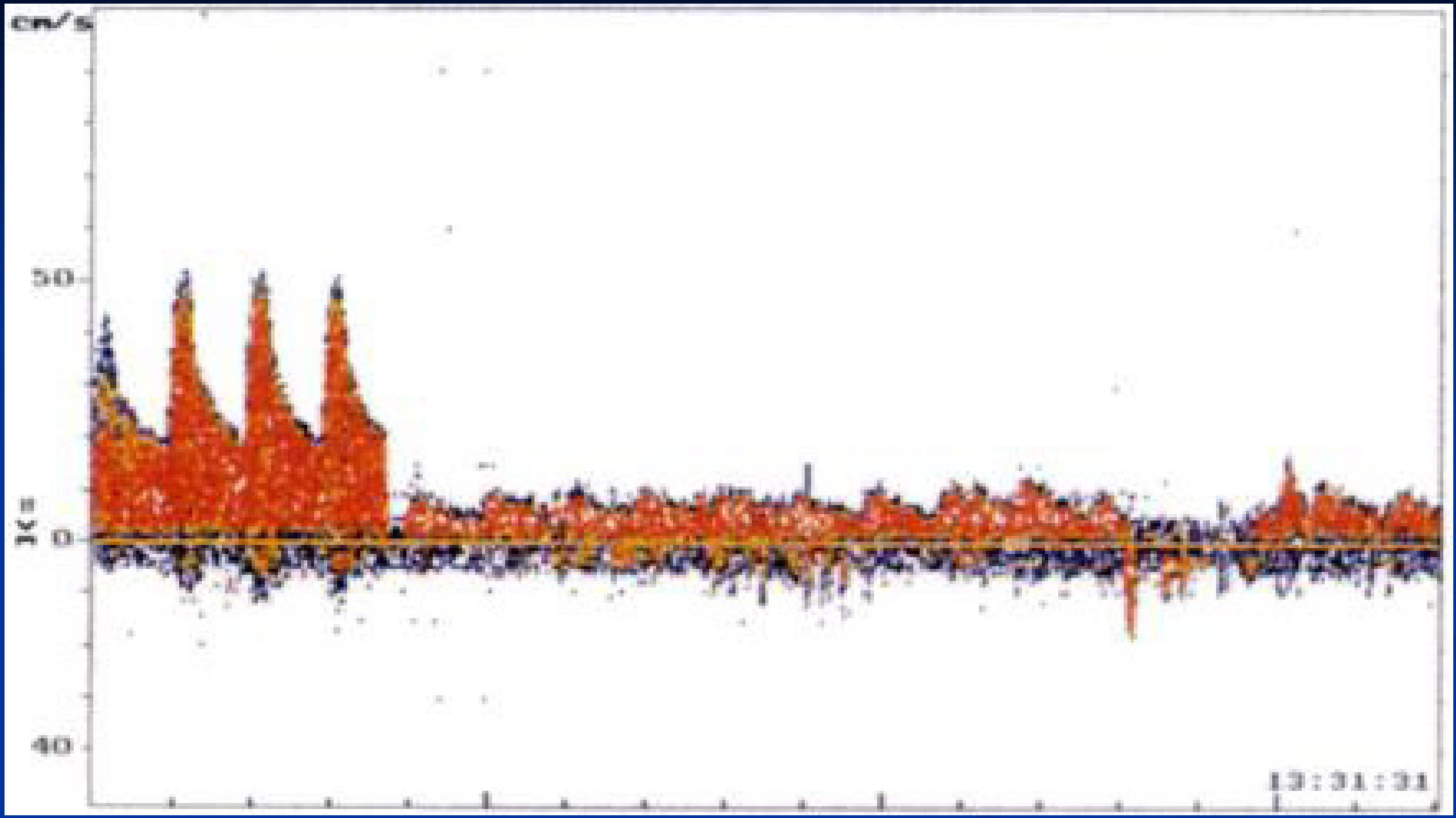
Color transcranial Doppler waveform demonstrates a decrease in blood flow velocity (estimated) in the ipsilateral middle cerebral artery *(MCA)* (mean velocity = 32 cm/see). *P1* = pulsatility index.

Intraoperative and Procedural Monitoring

- Carotid Endarterectomy
  - For cross-clamp Hypoperfusion
  - Detection of emboli
  - Postoperative hypoperfusion
  - Postoperative occlusion



Color transcranial Doppler waveform demonstrates normal blood flow velocity (estimated) in the right middle cerebral artery following cross-clamping, suggestive of adequate routes of inthcranial collateral circulation.



Color transcranial Doppler waveform demonstrates diminished blood flow velocity (estimated) in the right middle cerebral artery foblowing cross-clamping,

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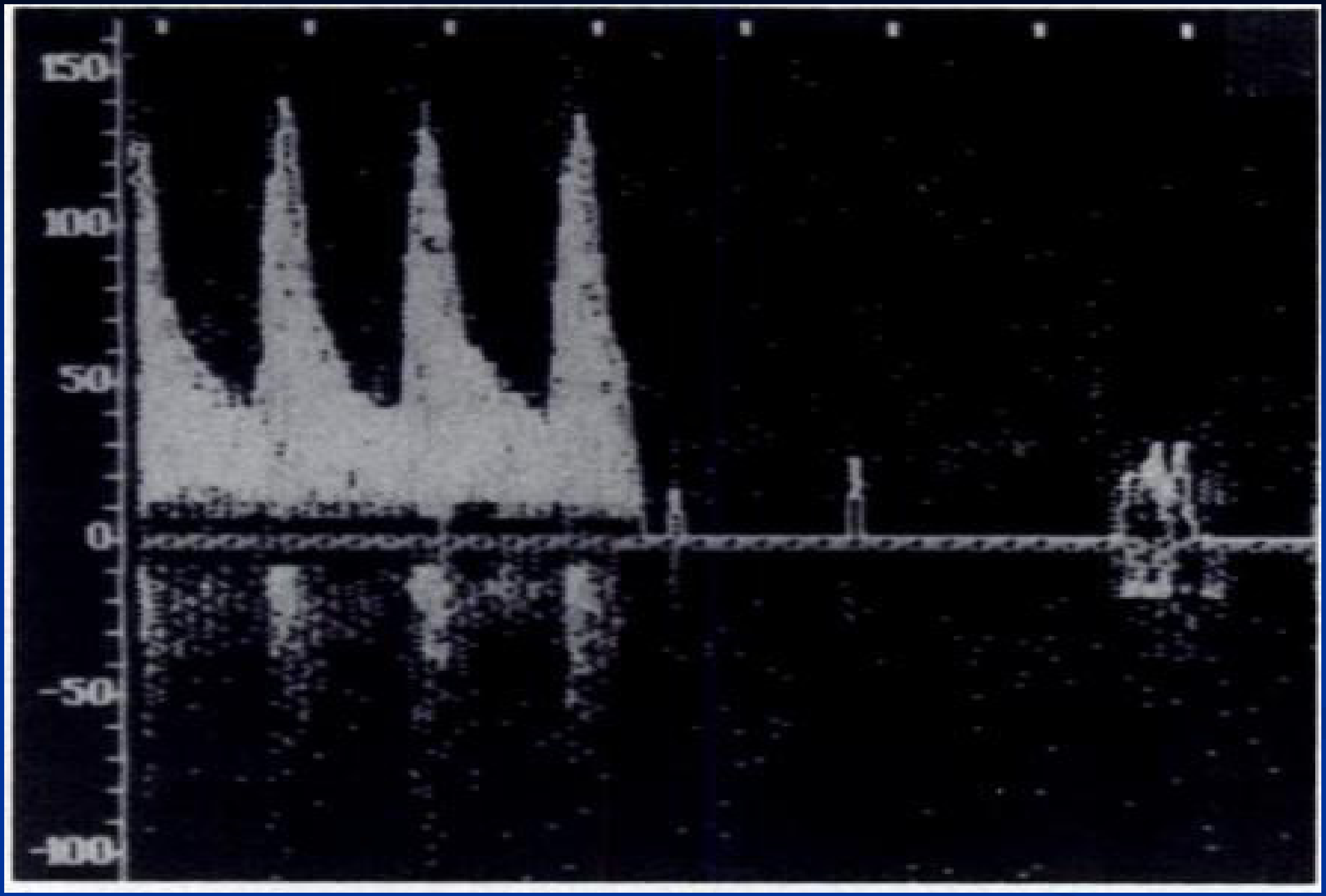
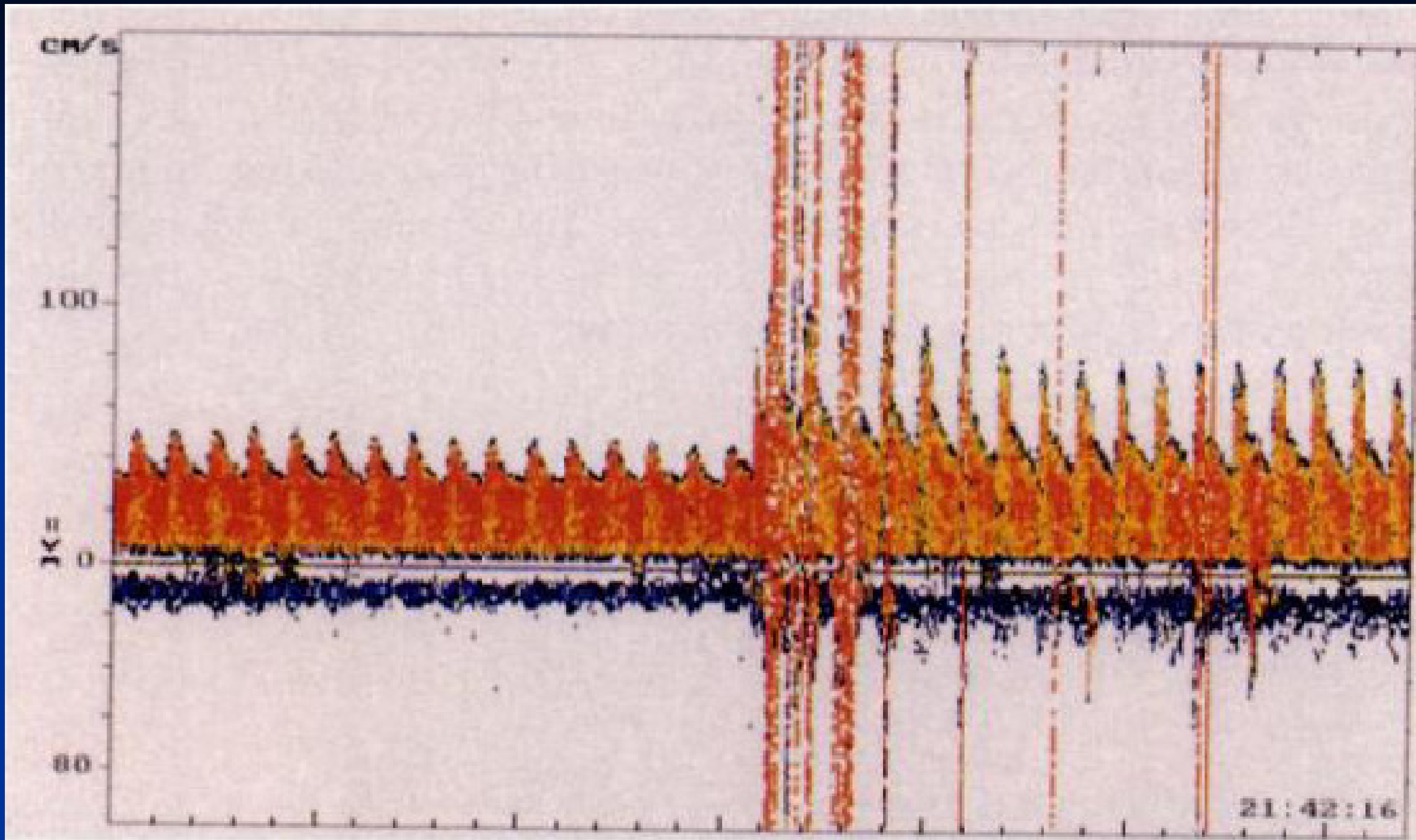
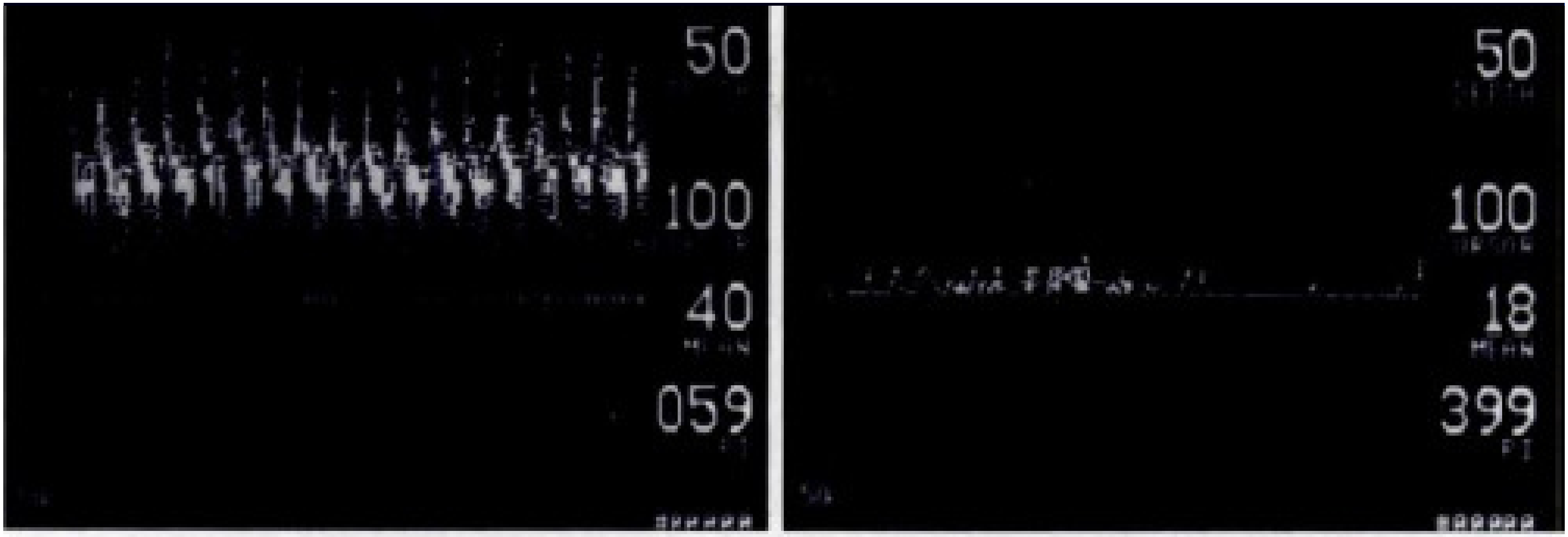


Transcranial Doppler waveform shows abrupt termination of blood flow in the right middle cerebral artery, secondary to kinking of the temporary intraluminal shunt.



Transcranial Doppler monitoring during carotid endarterectomy. Color transcranial Doppler waveform demonstrates an embolus

caused by manipulation at the endartenectomy site.



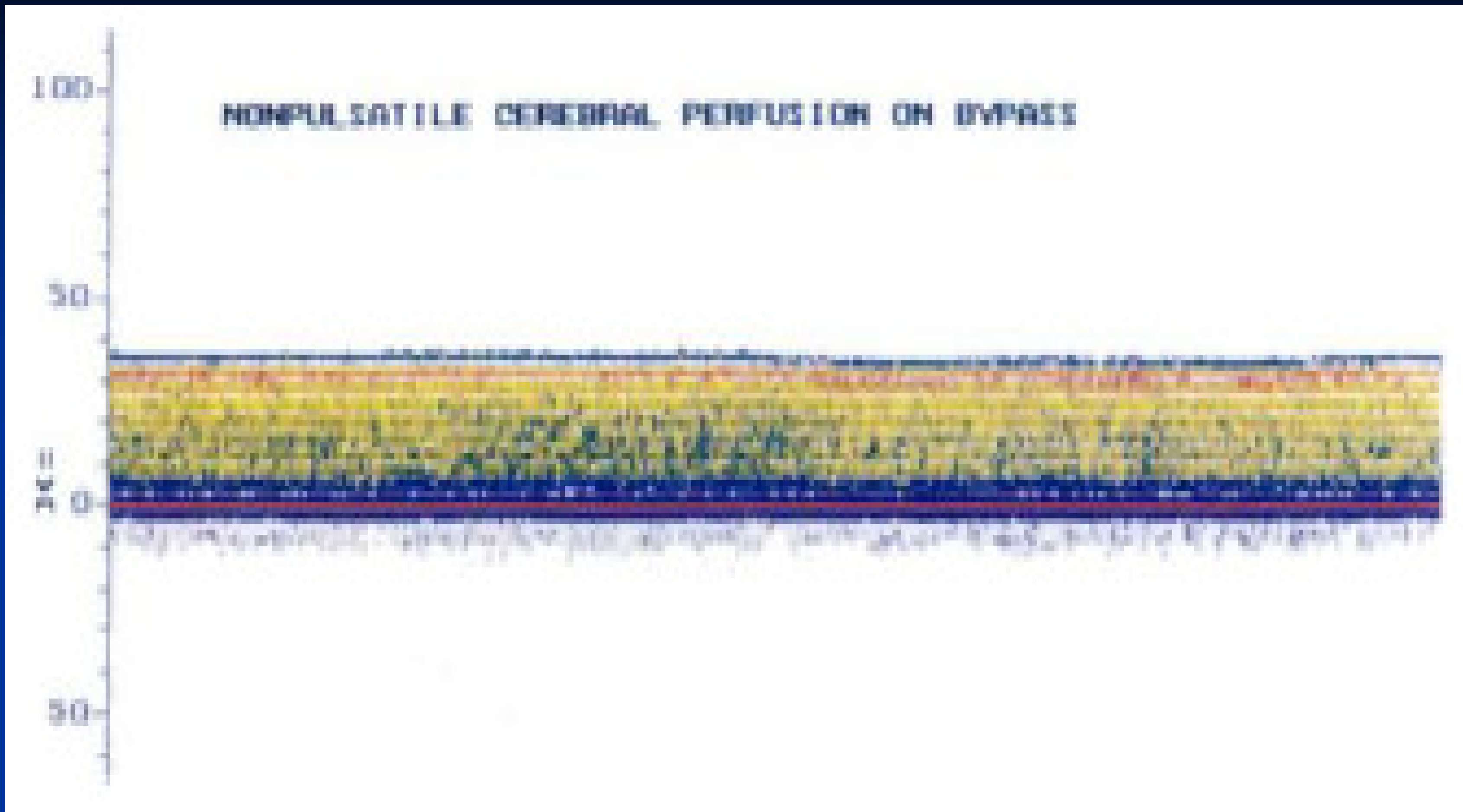
a.

b.

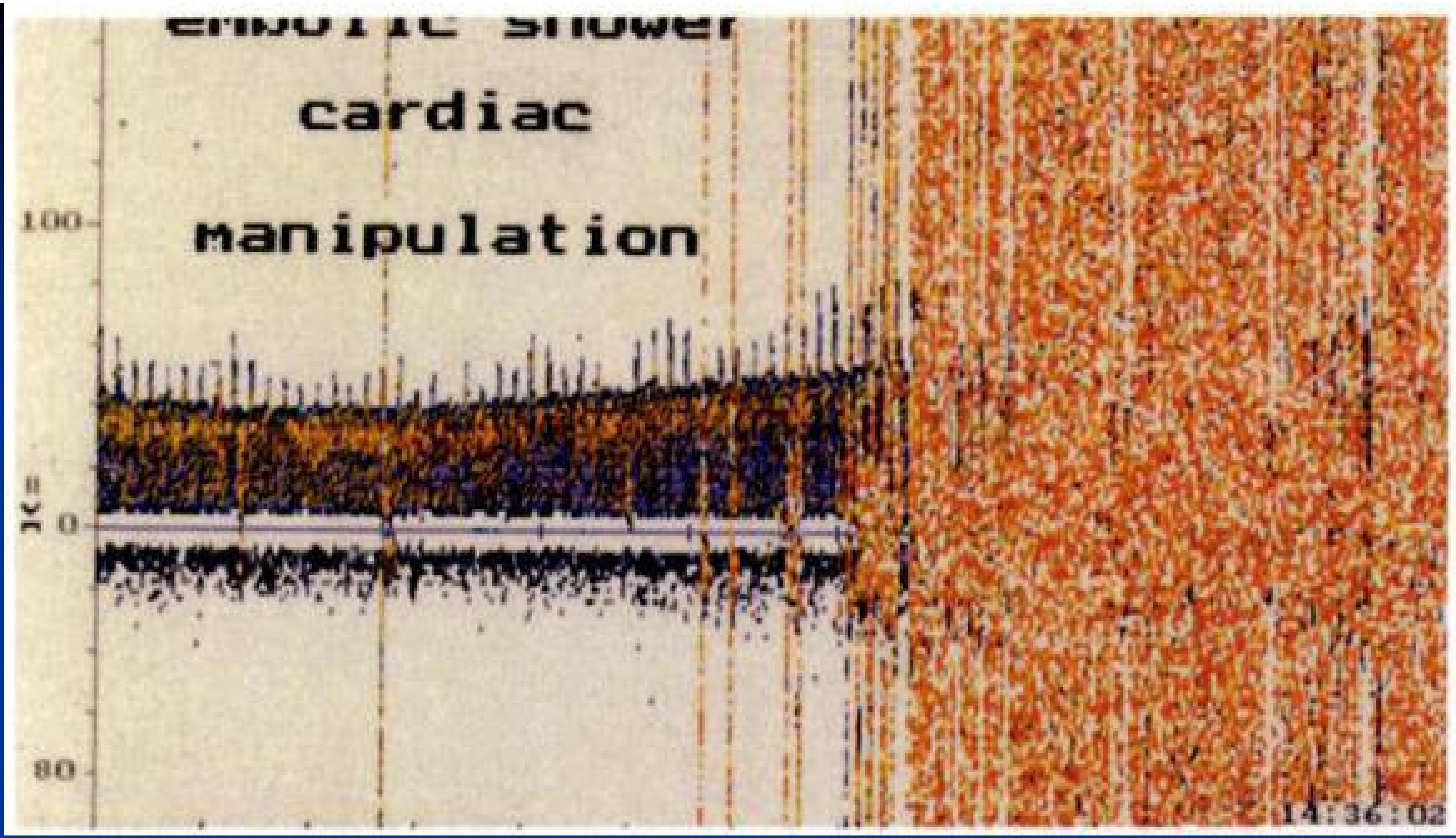
Figure 12. Endarterectomy thrombosis. **(a)** Transcranial Doppler waveform shows normal blood flow in the right middle cerebral artery at the completion of surgery. *PI* = pulsatility index. **(b, c)** Transcranial Doppler waveforms obtained during monitoring in the recovery room demonstrate markedly diminished **(b)** and then absent **(c)** blood flow in the right middle cerebral artery, suggestive of thrombosis at the endarterectomy site. Patient underwent surgery, with subsequent restoration of normal blood flow.

During Cardiopulmonary Bypass

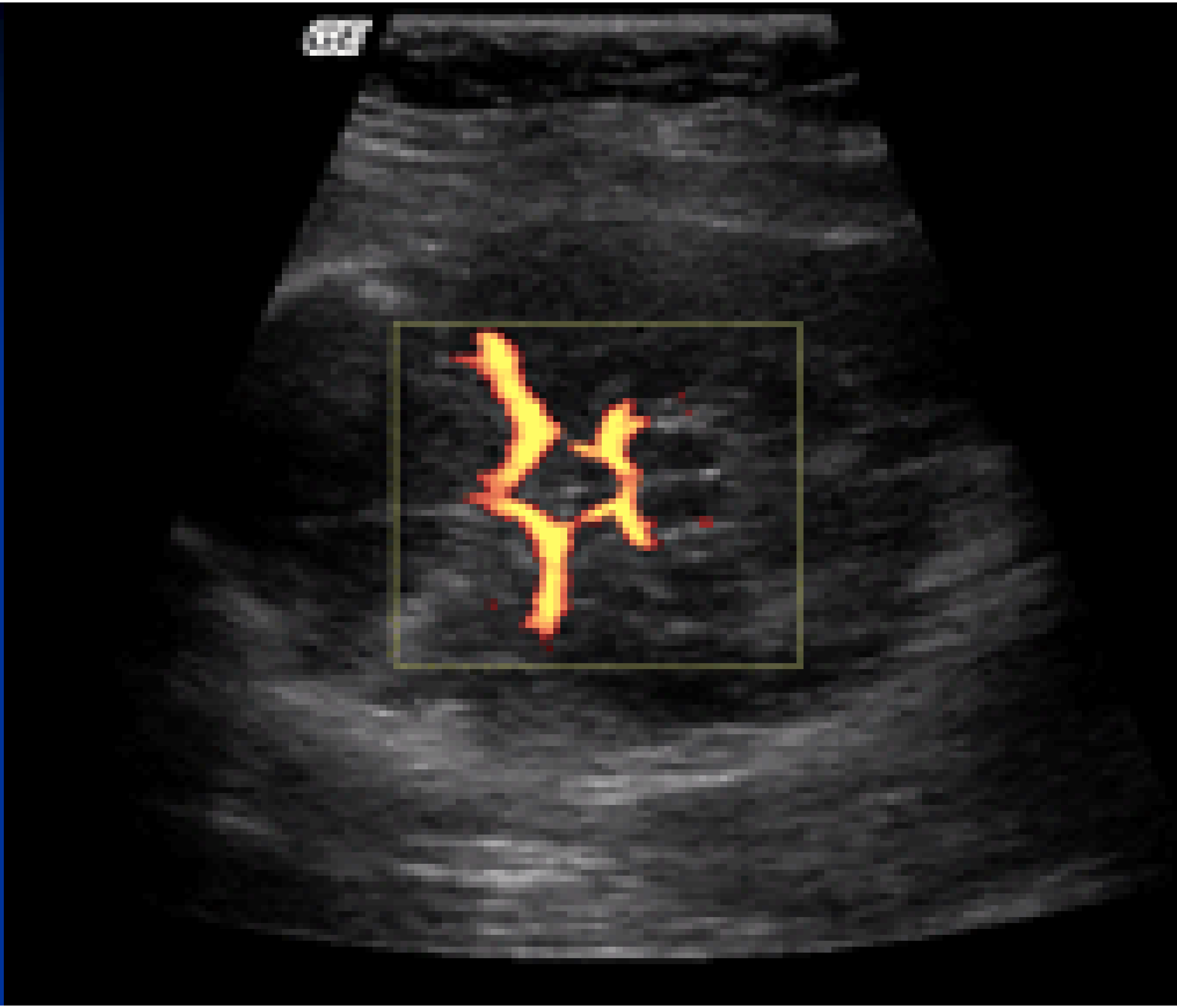
- Dynamic evaluation of cerebral blood flow
- Detection of emboli during aortic cannulation and cardiac manipulation



Transcranial Doppler monitoring during cardiopulmonary bypass for cardiac surgery. Color transcranial Doppler waveform demonstrates the typical nonpulsatile cerebral blood flow present during mechanical perfusion

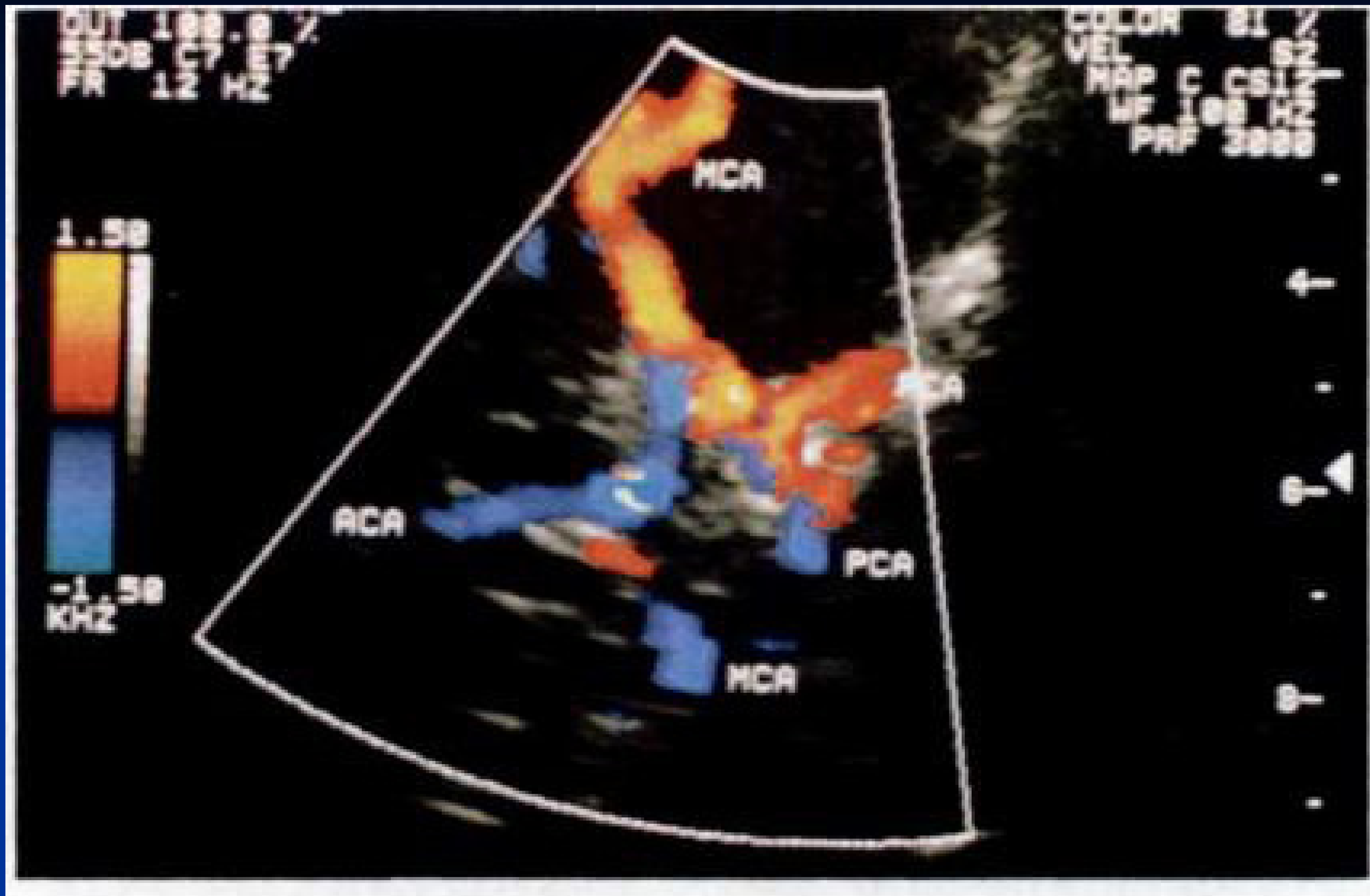


Transcranial Doppler monitoring during cardiac surgery. Color transcranial Doppler waveforms demonstrate emboli, which are frequently seen during cardiac manipulation



Latest development

- Transcranial colour coded Ultrasonography
- f-TCD



Colon transcranial Doppler image obtained on an Ultramark 9 ultrasound system (Advanced Technology Laboratories) shows the middle cerebral artery *(MCA),* anterior cerebral artery *(ACA),* and posterior cerebral artery *(PCA).* The high-definition imaging and transcranial Doppler options of the system enable color Doppler imaging of the circle of Willis and vertebrobasibar system with optimal vessel localization and sample volume placement.