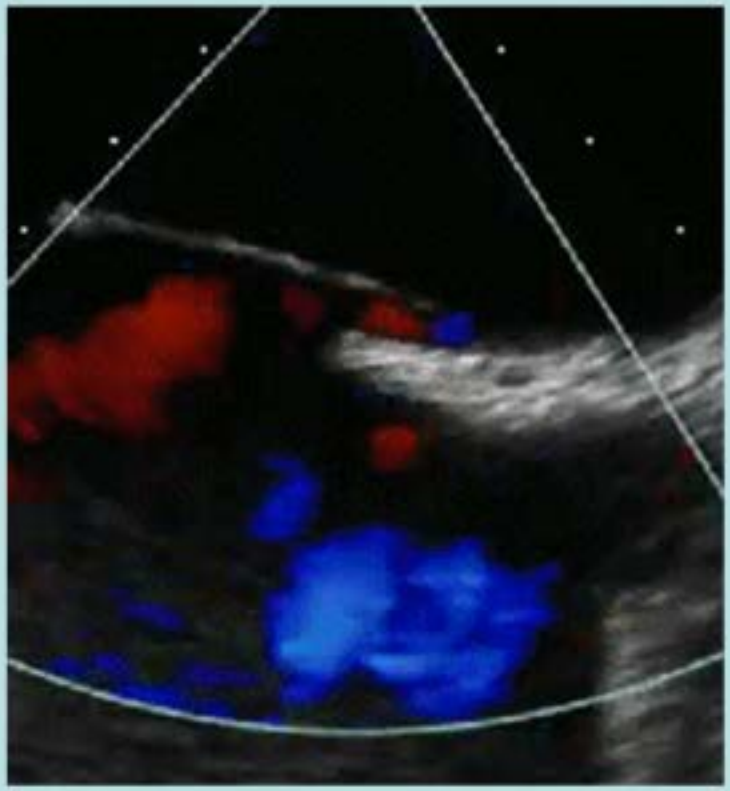
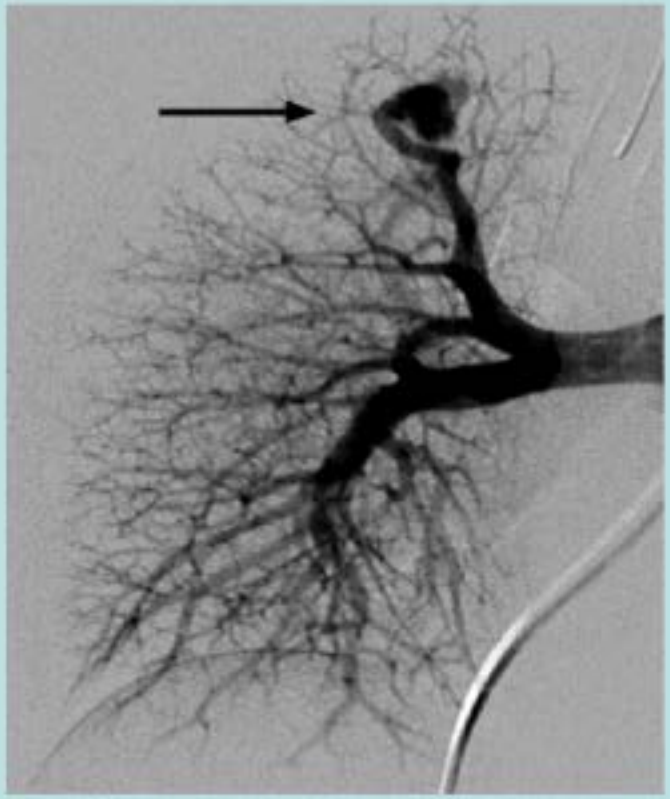
Cardiac / Pulmonary Right-Left-Shunt





pulmonary angiography - pAVM

Stroke risk in normals per year: 0.15 %

Recurrent Stroke/TIA rate per year:
< 1% - 17.5%

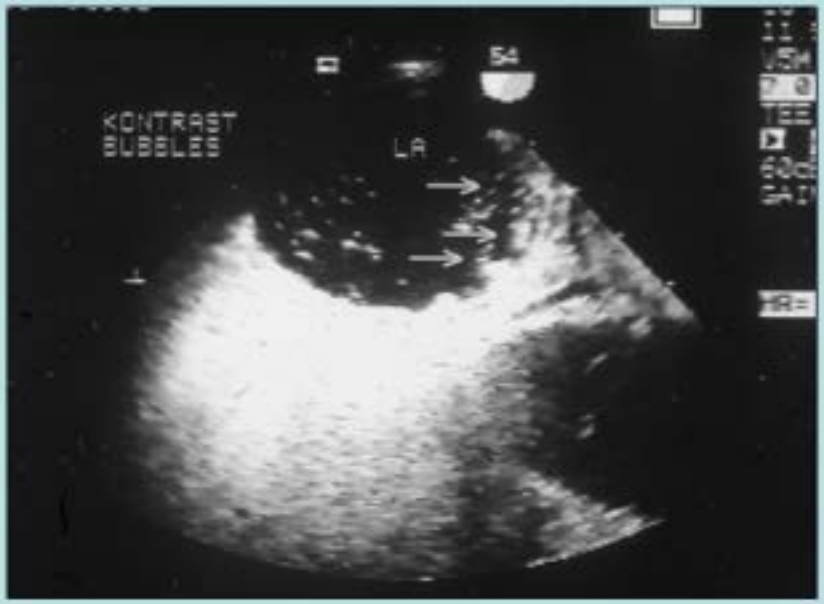
History of stroke/TIA: 18-37 %

Annual stroke risk: 1.5 %

Diagnostic Modalities / cTEE

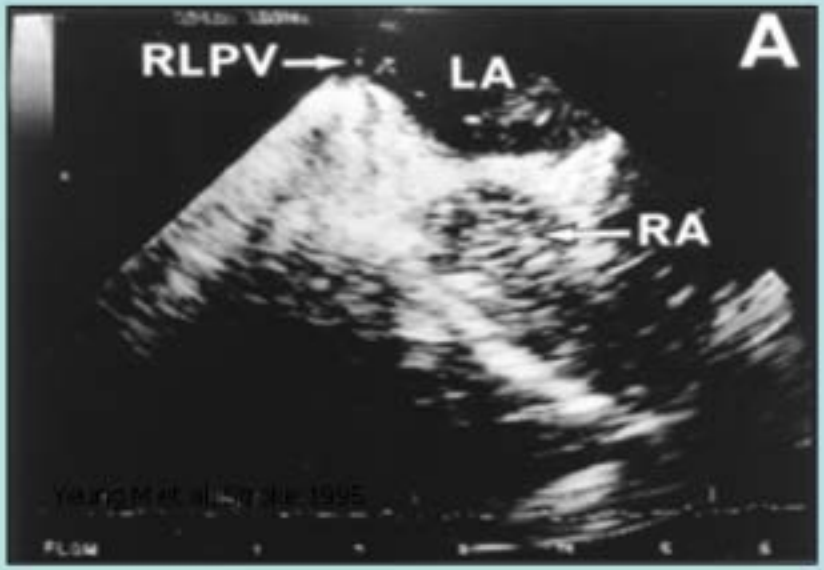
Cardiac RLS

- Contrast observed to cross the interatrial septum
- from the right to the left atrium
- within 3 cardiac cycles



Pulmonary RLS

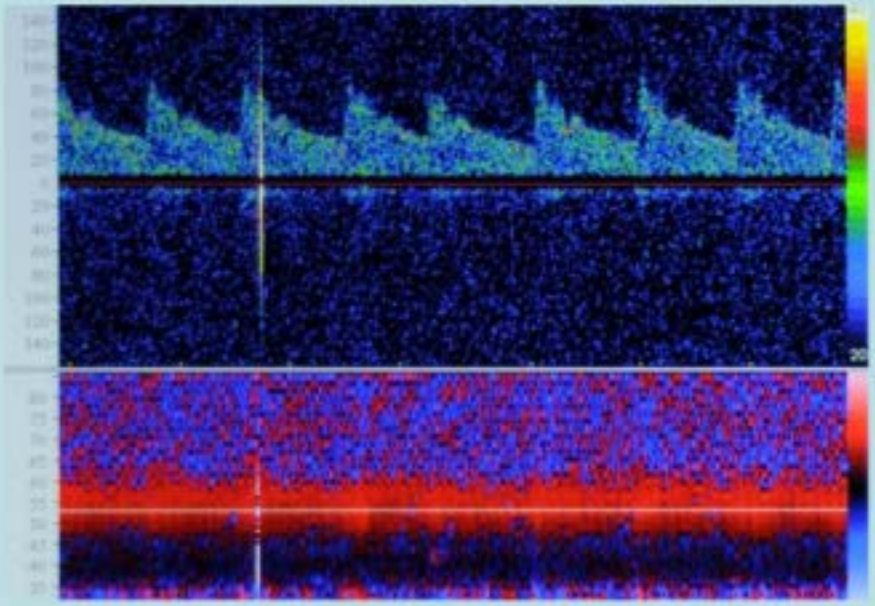
- Contrast observed in the left atrium
- late appearance (later than 5 cardiac cycles after right heart opacification)
- visualized to enter from pulmonary veins
- intact atrial/ventricular septa



Diagnostic Modalities / cTCD

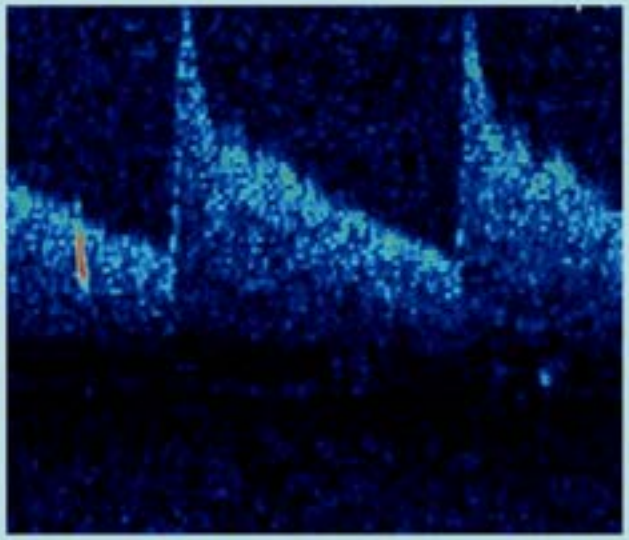
Definition RLS by cTCD

Appearance of at least one contrast induced microembolic signal (Mb) on the TCD trace after contrast injection.

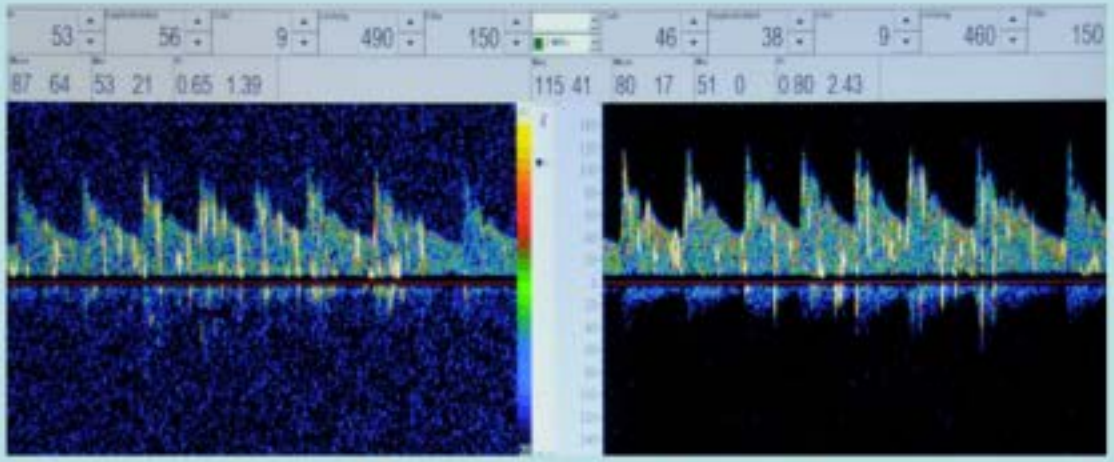


Contrast induced Microembolic Signals

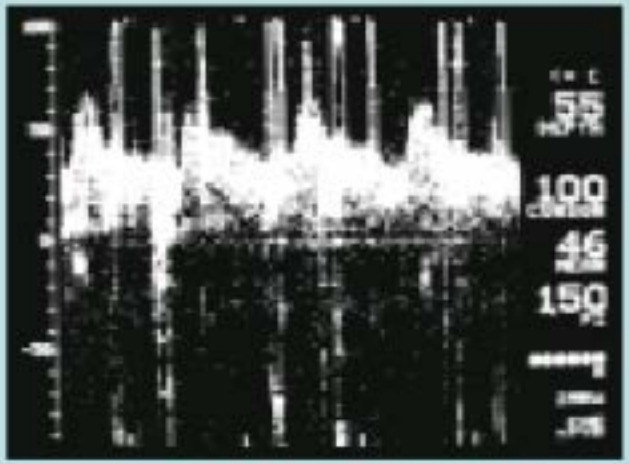
- Doppler High Intensive Signal Transients (HITS), Microembolic Signals (MES), Microbubbles (Mbs)
- high intensive, Doppler amplitude is at least 3 db higher than the background blood flow
- transient, short duration, usually lasting < 300 ms, (< 0.01-0.03 s)
- mostly unidirectional
- typical acoustic output („snap, chip or moan")



Solid emboli originating from ipsilateral ICA stenosis



Mb shower in PFO testing

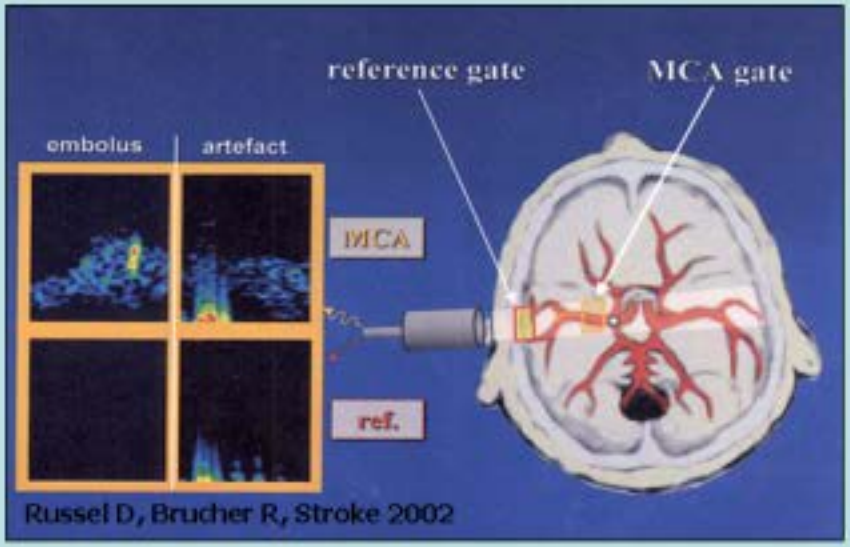


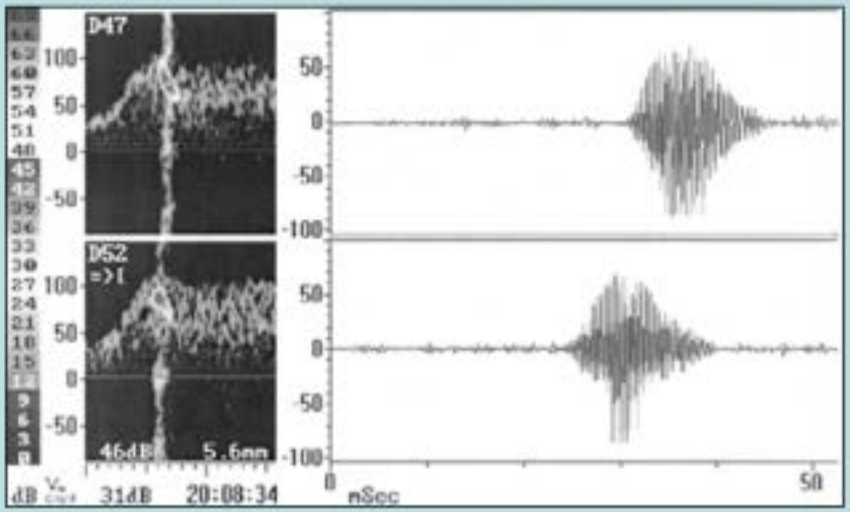
Gaseous emboli

Contrast induced Microembolic Signals
Solid vs Gaseous vs Artifact

- Solid emboli are difficult to differentiate from gaseous emboli
- Gaseous emboli have a higher amplitude
- are mostly bidirectional

- Artifacts are mostly bidirectional (zeroline)
- different acoustic output
- Automated systems combined with dual-gate TCD





Review: Patent Foramen Ovale and Stroke. Homma S, Sacco RL, Circulation, 2005

The TEE contrast study is the most sensitive diagnostic test available for detecting a PFO, followed by TCD and TTE contrast studies ($p < 0.001$) - for TEE versus TTE and for TCD versus TTE contrast studies.

Transcranial Doppler Ultrasonography in 2004: A comprehensive evidence-based update. Assessment of the American Academy of Neurology. Sloan MA, Alexandrov AV, Tegeler DH et al, Neurology 9/

Contrast TCD is comparable to contrast TEE for detecting right to left shunts due to PFO yielding a sensitivity of 70 -100% and a specificity of > 95% (Level A, Class II Evidence).

Consensus Statements and Publications concerning a practical Approach and Developement of a standardized Examination Protocol for RLS Detection using cTCD

Consensus Committee of the Ninth International Cerebral Hemodynamic Symposium. Basic identification criteria of Doppler microembolic signals. Ackerstaff R, Spencer MP et al, Stroke 1995

Consensus on Microembolus Detection by TCD. International Consensus Group on Microembolus detection. Ringelstein EB et al, Stroke 1998

Detection of right-to-left shunt with ultrasound contrast agent and transcranial Doppler sonography. Jauss M, Zanette EM for the Consensus Conference, Cerebrovasc Dis, 2000

Contrast-Enhanced Transcranial Doppler Ultrasound for Diagnosis of Patent Foramen Ovale. Nedeltchev K, Mattle HP (in: Baumgartner RW, Handbook on Neurovascular Ultrasound, 2006)

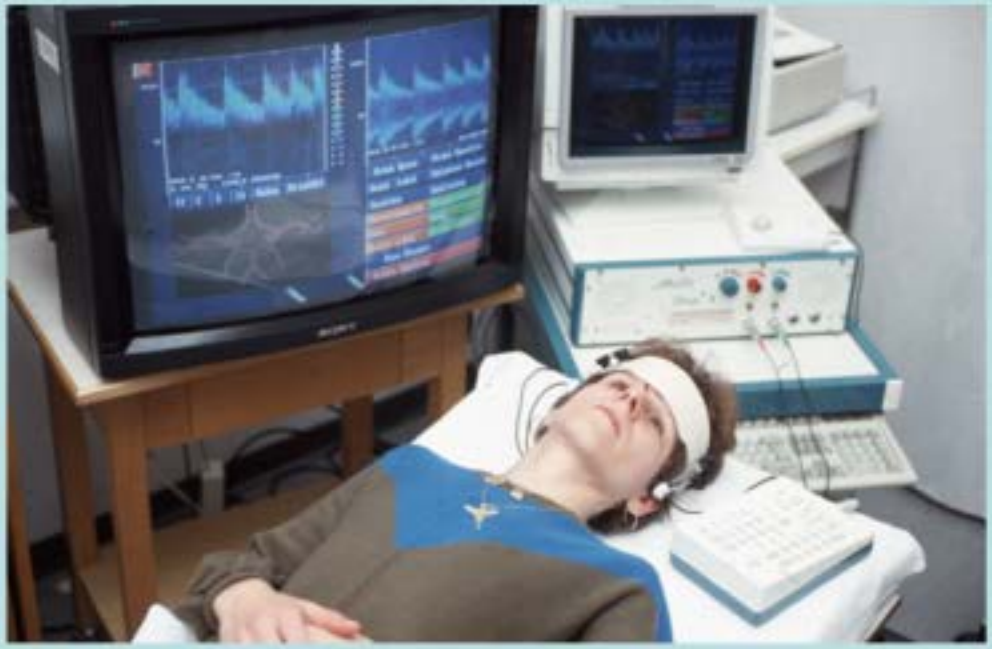
Clinical impact of patent foramen ovale diagnosis with transcranial Doppler. Anzola GP. Eur J Ultrasound 2002

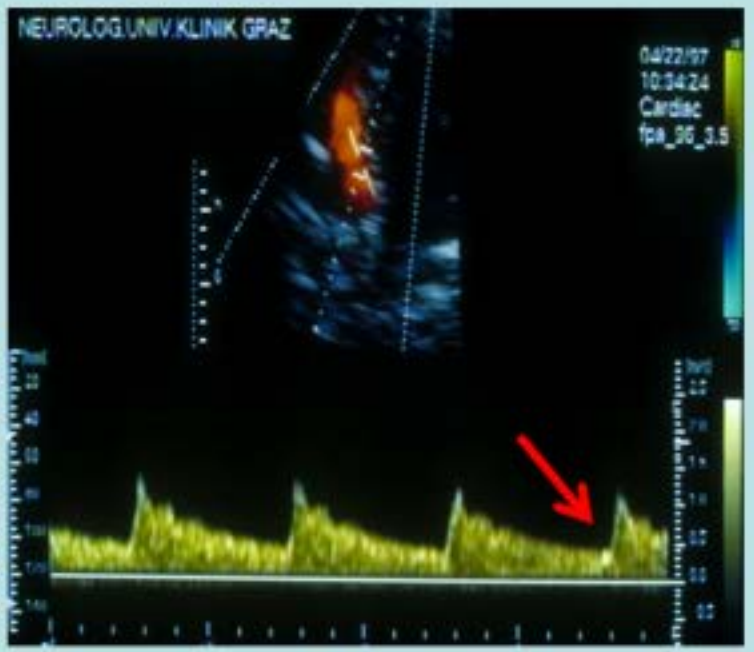
Patent Foramen Ovale. Horner S et al (in: New Trends in Neurosonology and Cerebral Hemodynamics – an Update. (Bartels E, Bartels S, Poppert H. Perspectives in Medicine, 2012

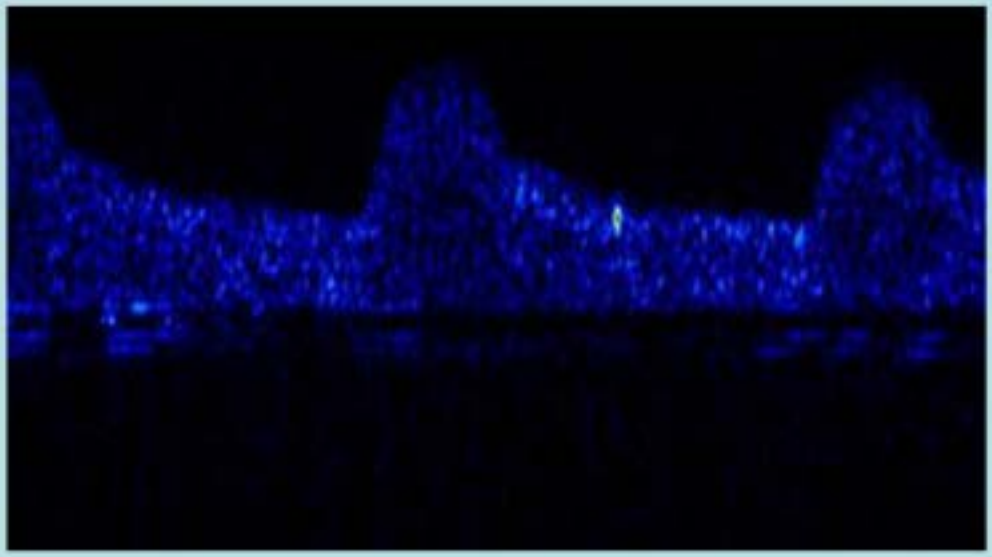
cTCD Monitoring Protocol

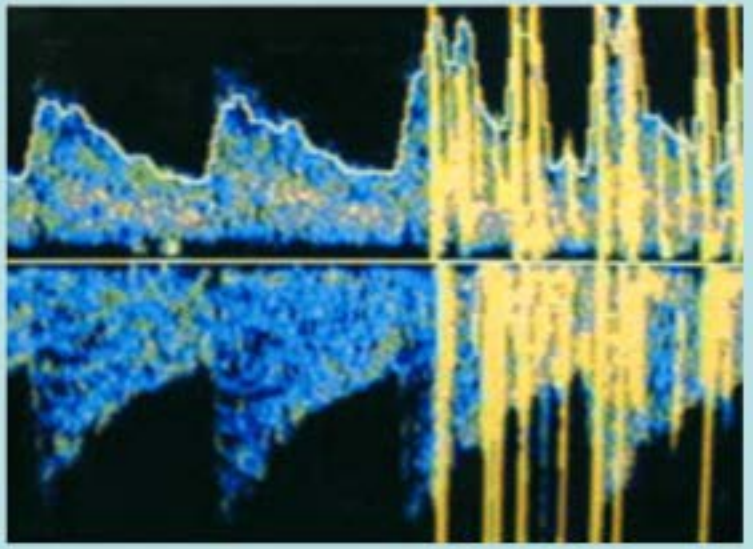
- 2-MHz TCD probe (s) placed on temporal bone window (basilar artery, extracranial ICA)
- manuelly held (unilateral TCD)
- fixed to the skull (bilateral TCD)
- Left and/or right MCA is monitored at usually 5-6 cm depth
- initially recording for at least 20 min for detection of spontaneous emboli (AF, carotid stenosis)
- Documentation of the FFT signal eg on computer disc, digital audiotapes/offline analysis

cTCD Monitoring Protocol









cTCD Monitoring Protocol

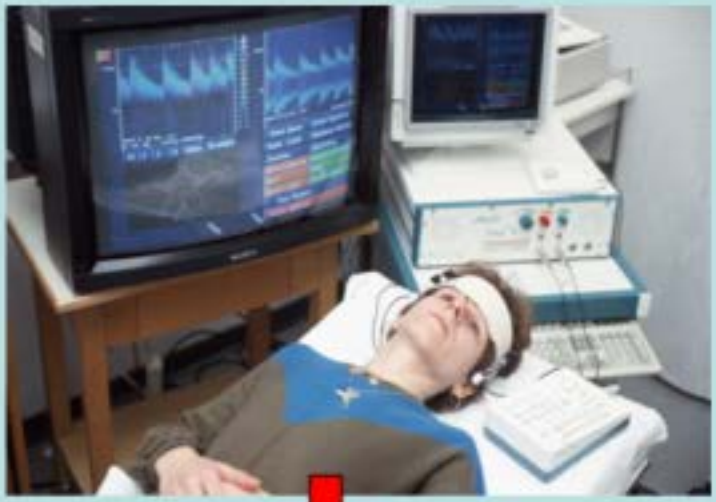
Patient preparation

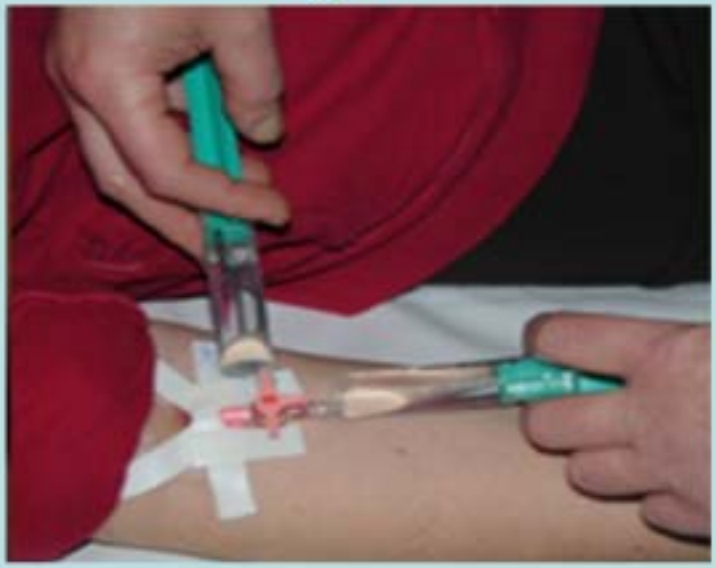
- supine position
- arm horizontal

Injection site

- preferably right antecubital vein
- iv line (18 or 20 gauge needle on a butterfly with a short flexible line to a 3-way stopcock

Preparation of contrast medium





cTCD Monitoring Protocol

Contrast agent / Dose and Preparation

agitated saline/air mixture:

- Syringe 1: 9 ml saline
  Syringe 2: 1 ml air
- forth exchanges for at least 10 times
- (0.5 ml patients blood)

Oxypolygelatine / ~~Echovist®~~

as proposed by manufacturer (Braun, Schering)

cTCD Monitoring Protocol

Contrast agent / Application

- immediately after preparation
- bolus injection (1ml per sec)
- flush – 0.9% saline (Echovist®)

- first testing without Valsalva maneuver (VM)
- if positive: permanent shunting is ensured
- if negative: repeated testing with VM to evaluate functional (latent) shunting

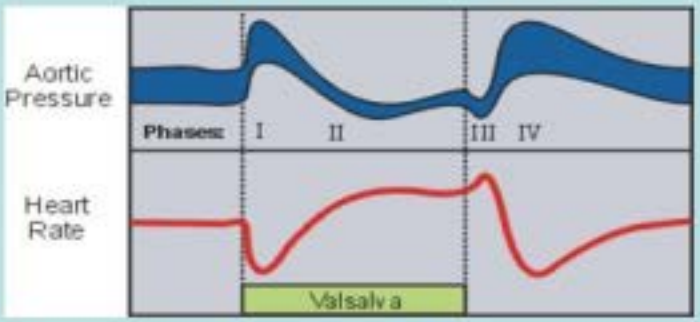
- training of VM with patient before contrast application

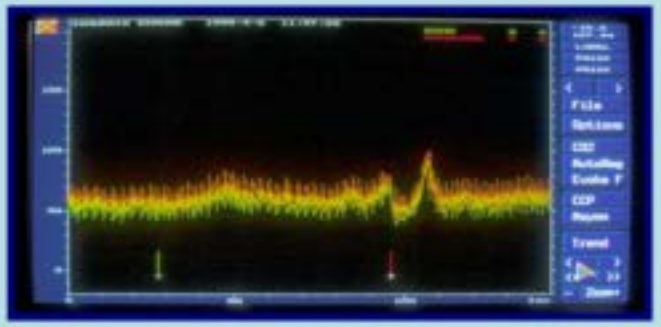
cTCD Monitoring Protocol

Valsalva maneuver (VM)

- inhalation followed by exhalation against closed glottis
- gauged VM (sphygomanometer at 40-60 mmHg)
- increase of thoracic pressure and right atrium, decrease of heart rate followed by overshooting of blood pressure
- controlling of correct performance by observing the decrease of the MCA peak flow velocity (TCD envelope)

- correct timing of VM: start 5 sec after contrast application
- duration of VM: maintain for at least 5-10 sec





cTCD Monitoring Protocol

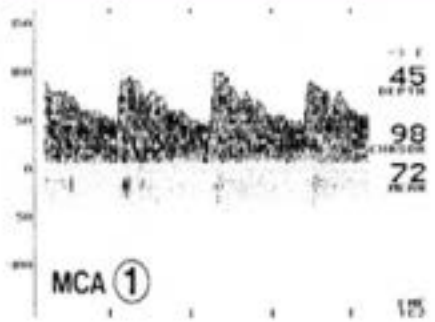
Evaluation of test results

- Mb **count** and **categorization**
- assessment of the **time interval** (embolic delay between contrast injection start and appearance of Mb, sec or cardic cycles)
- performance and evaluation of both tests separately with and without VM
- test results might be influenced by:
  contrast agent, dose, application mode, VM, hemodynamic parameters/heart rate…

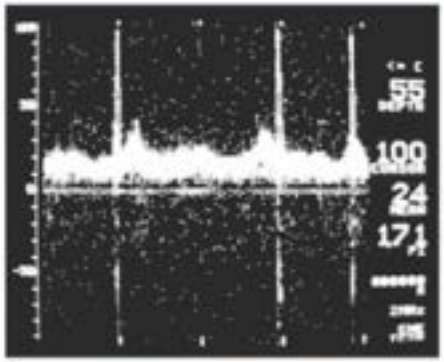
cTCD Monitoring Protocol
Count and Categorization / Test Result

	unilateral TCD Monitoring	bilateral TCD Monitoring
Cat 1 shunt negative	no Mb	no Mb
Cat 2 low-grade	1-10	1-20
Cat 3 medium-grade	> 10	> 20
Cat 4 high-grade	shower	shower

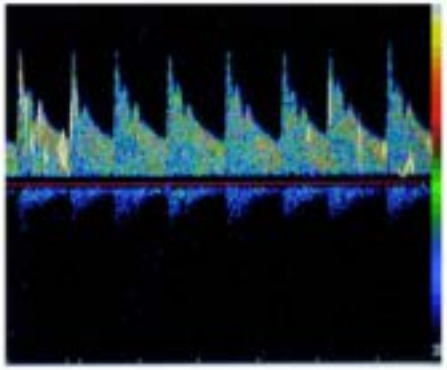
Cat 1



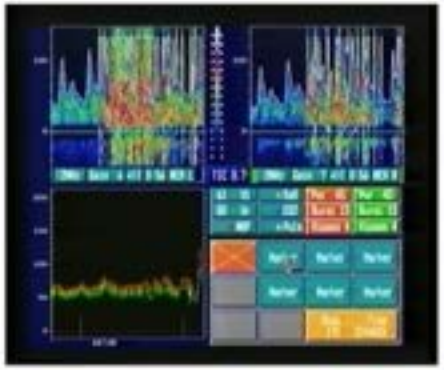
Cat 2



Cat 3



Cat 4



- shunt negative
- shunt positive

- permanent shunt
- functional shunt

- grading

Clinical Usage of cTCD in Stroke

- TCD cannot replace TEE. TEE is required in all cryptogenic (young) stroke patients to confirm: site of the shunt, size of PFO, ASA, thrombus and other cardiac abnormalities)
- TCD may serve as an alternative method if TEE is not applicable or available
- TCD can be useful during the acute phase of routine ischemic stroke workup for early detection and sizing of RLS and to identify the pathogenic mechanisms of stroke
- and to make timely decisions to perform TEE