Transkraniaalne Doppler

Elena Kalinina
R-3

TCD

- Põhineb Doppler effektil
- Saab hinnata nii pindmiselt, kui ka sügavamal paiknevaid struktuure (kuni ~6cm sügavuseni)
- Kuna tegemist on n.ö. pimeda uuringuga, erinevaid veresooni saab identifitseerida akna, sügavuse ning voolukõvera järgi

Kasutamisvõimalused

Table 4: TCD applications [2, 4, 18, 39–41]. Categorised as per reference [39].

Ischaemic cerebrovascular disease
Sickle cell disease
Right to left cardiac shunts
Intra and extra-cranial arterial steno-occlusive disease
Arteriovenous malformations and fistulas
Peri-procedural/operative
Cerebral thrombolysis in acute stroke
Carotid endarterectomy
Carotid angioplasty and stenting
Coronary artery bypass surgery
Coronary angioplasty
Prosthetic heart valves
Neurological/Neurosurgical intensive care
Vasospasm after subarachnoid haemorrhage
Raised intracranial pressure
Head injury
Cerebral circulatory arrest and brain death
Intracerebral aneurysm and parenchymal hematoma detection
Others
Pharmacologic vasomotor testing
Cerebral pressure autoregulation
Liver failure/Hepatic encephalopathy
Preeclampsia

Kliinilised näidustused

Table 15.2 Established clinical indications for and expected outcomes of TCD testing

Broad indication	Specific indications	Expected outcomes
Sickle cell disease	Children	Robust first-ever stroke risk reduction based on TCD criteria for the need of blood transfusion and continuing use of blood transfusions
Ischemic stroke or TIA	Patients with acute ischemic symptoms who had cranial CT or MRI	TCD can identify patients with proximal arterial obstructions in the anterior and posterior circulation, identifying patients amenable to reperfusion therapies (intravenous thrombolysis or endovascular therapy)
Ischemic stroke or TIA	Patients with subacute ischemic symptoms who had cranial CT or MRI	TCD helps determine stroke pathogenic mechanism that in turn determines secondary stroke prevention treatment. TCD also helps to localize and grade intracranial atheromatous disease process, (anterior vs. posterior vessels, diffuse vs. local disease, ≥70% stenosis that indicate high risk of stroke recurrence)
Ischemic stroke or TIA	Symptomatic patient at any time window who underwent carotid duplex scanning	Carotid duplex ultrasound may explain only 15–25% of all ischemic events since the prevalence of ≥50% proximal ICA stenosis is low. TCD has the ability to further refine stroke mechanism detection by determining the presence of intracranial steno-occlusive disease, embolization, shunting, and impaired vasomotor reactivity
Ischemic stroke or TIA	Patients with undetermined stroke mechanism, recurrent TIAs, artery-to-artery versus cardiac source of embolism, suspected arterial dissections	TCD is the gold standard test to detect, localize, and quantify cerebral embolism in real time. No other modality offers spatial and time resolution to detect microembolic activity, localize its source (artery vs. heart), and confirm vascular etiology of patient symptoms
Ischemic stroke or TIA	Patients with suspected paradoxical embolism with negative echocardiography	TCD is equal or superior in its sensitivity to the presence of any right-to-left shunt compared to echocardiography (Valsalva maneuver is best accomplished during TCD; extracardiac shunting can be detected with TCD but not TEE)
Ischemic stroke or TIA	Follow-up	TCD is an inexpensive noninvasive follow-up tool that can detect progression or regression in the severity of extra- and intracranial stenosis through direct velocity measurements, collaterals, and vasomotor reactivity assessment
Asymptomatic or symptomatic carotid artery stenosis or occlusion	Patients who have ICA stenosis or occlusion on carotid duplex or angiography	TCD can help identify patients at highest risk of first-ever or recurrent stroke in the setting of an ICA stenosis of variable degree or complete occlusion. TCD findings of artery-to-artery embolization and impaired vasomotor reactivity indicate three—fourfold higher risk of stroke compared to patients with similar degree of ICA stenosis and normal TCD findings
Subarachnoid hemorrhage	Day 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
	Day 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
	Day 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 subarachnoid hemorrhage
Suspected brain death	Increased intracranial pressure	TCD can rule out cerebral circulatory arrest if positive diastolic flow is detected at any ICP values. TCD can confirm clinical diagnosis of brain death by demonstrating complete cerebral circulatory arrest in anterior and posterior circulation
Peri-procedural or surgical monitoring	Carotid endarterectomy or stenting	TCD can detect all major causes of perioperative complications, i.e., embolism, thrombosis, hypoperfusion, and hyperperfusion. TCD detects real-time flow changes that precede the development of neurological deficits or changes on electroencephalography

Plussid ja miinused

Box 2: Pros and cons of transcranial Doppler ultrasound

Usefulness

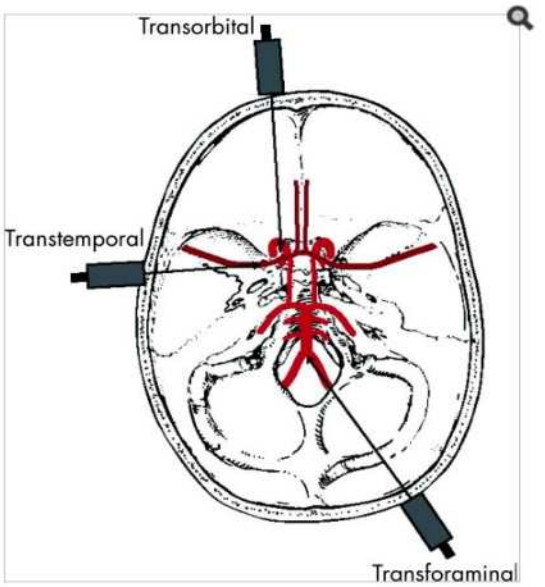
- Safe, non-invasive
- Bedside technique providing useful information on intracerebral vasculature
- Detection of micro-emboli—useful for prediction of early recurrence of stroke/TIA
- Useful tool in investigation of cryptogenic stroke—with use of echo contrast agent
- Adjunct to extracranial duplex carotid sonography in determining the effects on cerebral haemodynamics

Drawbacks

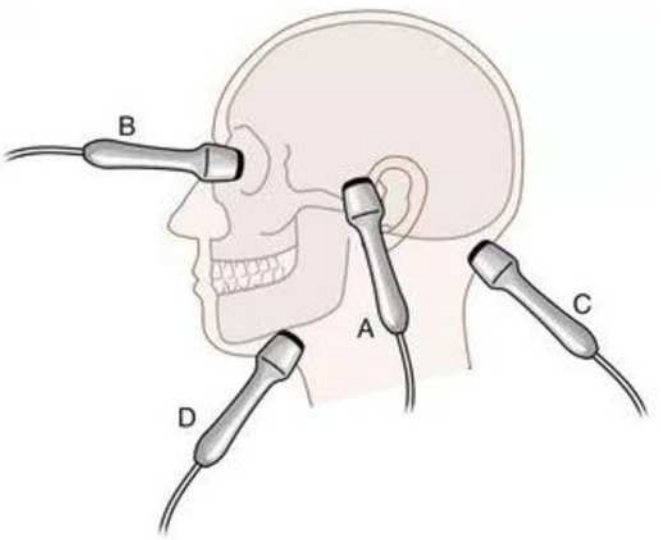
- Inaccuracy due to poor acoustic window (in up to 5–20%)
- Highly operator dependent and requires considerable skill and experience for accurate interpretation

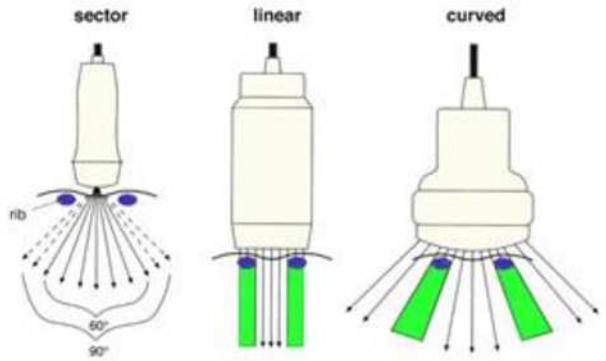
Tehniline teostamine

- Transtemporaalne aken
- Transorbitaalne aken
- Transforaminaalne aken
- Retromandibulaarne aken
- 1-5MHz sektor andur



:essing the intracranial arteries.





Aknad

Table 1: Insonation characteristics of the cerebral vasculature. Adapted from Nicoletto and Burkman [3]. Permission obtained; copyright owner ASET (American Society of Electroneurodiagnostic Technologists), the Neurodiagnostic Society.

Artery	Acoustic window	Probe angle	Depth (mm)	Flow direction	Resistance	Adult MFV (cm/sec)
ECICA	Retromandibular	Superior-medial	45–50	Away	Low	30 ± 9
MCA	Middle transtemporal	Straight/Anterior-superior	30–65	Toward	Low	55 ± 12
ACA	Middle transtemporal	Straight/Anterior-superior	60–75	Away	Low	50 ± 11
PCA—segment 1	Posterior transtemporal	Straight/Posterior	60–70	Toward	Low	39 ± 10
PCA—segment 2	Posterior transtemporal	Straight/Posterior-superior	60–70	Away	Low	40 ± 10
BA	Suboccipital	Superior	80–120	Away	Low	41 ± 10
VA	Suboccipital	Superior lateral	60–75	Away	Low	38 ± 10
OA	Transorbital	Straight	45–55	Toward	High	21 ± 5
Supraclinoid ICA	Transorbital	Superior	65–80	Away	Low	41 ± 11
Parasellar ICA	Transorbital	Inferior	65–80	Toward	Low	47 ± 14

(ECICA: extracranial internal carotid artery, MCA: middle cerebral artery, ACA: anterior cerebral artery, PCA: posterior cerebral artery, BA: basilar artery, OA: ophthalmic artery).

Hinnatavad näitajad. MFV

- MFV – keskmine voolukiirus (mean flow velocity)
- Kõrge – stenoos, vasospasm, hüperdünaamiline vool
- Madal – hüpotensioon, madal ajusisene rõhk, ajuverevarustusehäire, ajusurm
- Fokaalse vasospasmi või stenoosi puhul on tüüpiline keskmise voolukiiruse tõus 5-10mm pikkusel alal ~30cm/s võrra võrreldes asümptomaatilise poolega

MFV mõjutavad faktorid

Table 2: Factors influencing MFV [18, 20].

Factor	Change in MFV
Age	Increases up to 6–10 years of age then decreases (see [26] for a full range of values)
Sex	Higher MFV in women than men
Pregnancy	Decreased in the 3rd trimester
PCO_2	Increases with increasing PCO_2
Mean arterial Pressure (MAP)	Increases with increasing MAP (CBF autoregulates between CPP 50–150 mmHg)
Haematocrit	Increases with decreasing haemotocrit

Hinnatavad näitajad. PI

- PI – Goslingu pulsatsiooni indeks (Gosling's pulsatility index). Annab infot ajuveresoonte resistentsuse kohta. Normväärtus 0,5–1,19. proksimaalse oklusiooni puhul <0,5 (sekundaarse vasodilatatsiooni tõttu), samuti võib viidata AV malformatsioonile. Distaalse oklusiooni puhul aga >1,19.
- On seotud ICP väärtusega

Hinnatavad näitajad. RI

- RI – Pourcelot resistentsuse indeks (Pourcelot resistivity index). Samuti vajalik ajuveresoonte resistentsuse hindamiseks. Loetaktse kõrgeks, kui on > 0,8. Peaks hindama koos PI-ga.

Hinnatavad näitajad. LI

- LI – Lindengaard suhe (Lindengaard ratio) vajalik hüperdünaamilise voolu ja vasospasmi eristamiseks.
- MCA keskmine voolukiirus/ekstrakraniaalse ICA keskmise voolukiirusega.
- < 3 hüperdünaamiline vool, > 3 vasospasm
- Modifitseeritud LI BA hindamiseks: BA MFV/keskmise vasaku ja parema VA MFV-ga;
- Sloan'i ajupoolkerade suhe (ACA MFV/ ekstrakraniaalse ICA MFV-ga)

Hinnatavad näitajad.

- BHI – hinge kinni hoidmise indeks (breath holding index). Peegeldab vasomotoorset reaktsiooni hüpo ja hüperkapniale. On abiks vasomotoorse reservi määramisel (VMR), mille abil saab omakorda määrata peaajuinfarkti ohtu.
- CBF-V max − CBF-V min)/hingamisseiskuse aeg) × 100
- Norm BHI >0.6, 0.21– 0.60 madal VMR, ≤0.20 oluliselt langenud VMR

MES

- MES – mikroemboolilised signaalid. Kasulikud intraoperatiivse monitooringu käigus (parem-vasak šuntide puhul, karotiidstenoosiga patsientidel selgitamaks operatsiooi vajavaid patsiente
- Salvestamiseks spetsiaalne aparatuur

(a)

Mikroembolid

- Saab detekteerida suuremaid või gaasemboleid
- Annavad lühiaegset signaali (<300ms)
- On kõrge amplituudiga (> 3dB kui põhivool)
- Ei sõltu südame tsüklist
- Annab tüüpilist häält
- Uurida vähemalt 30min

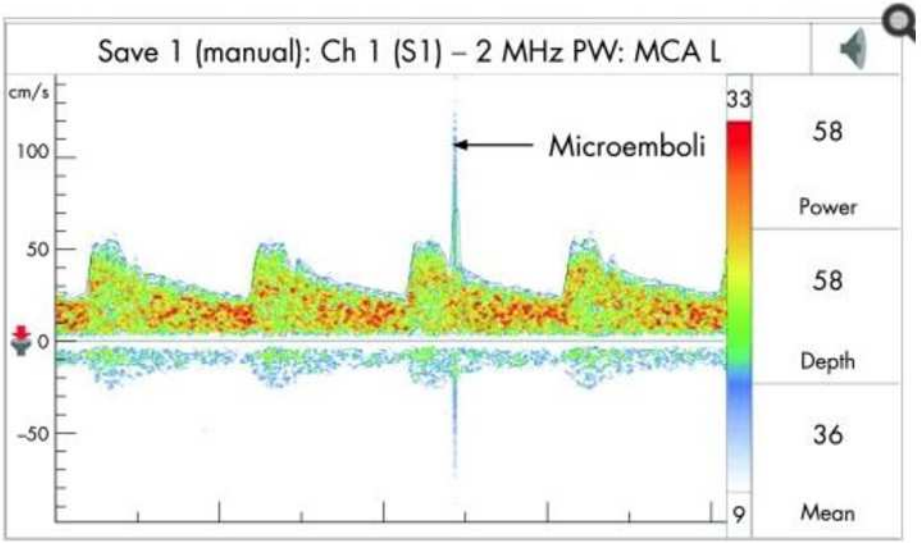
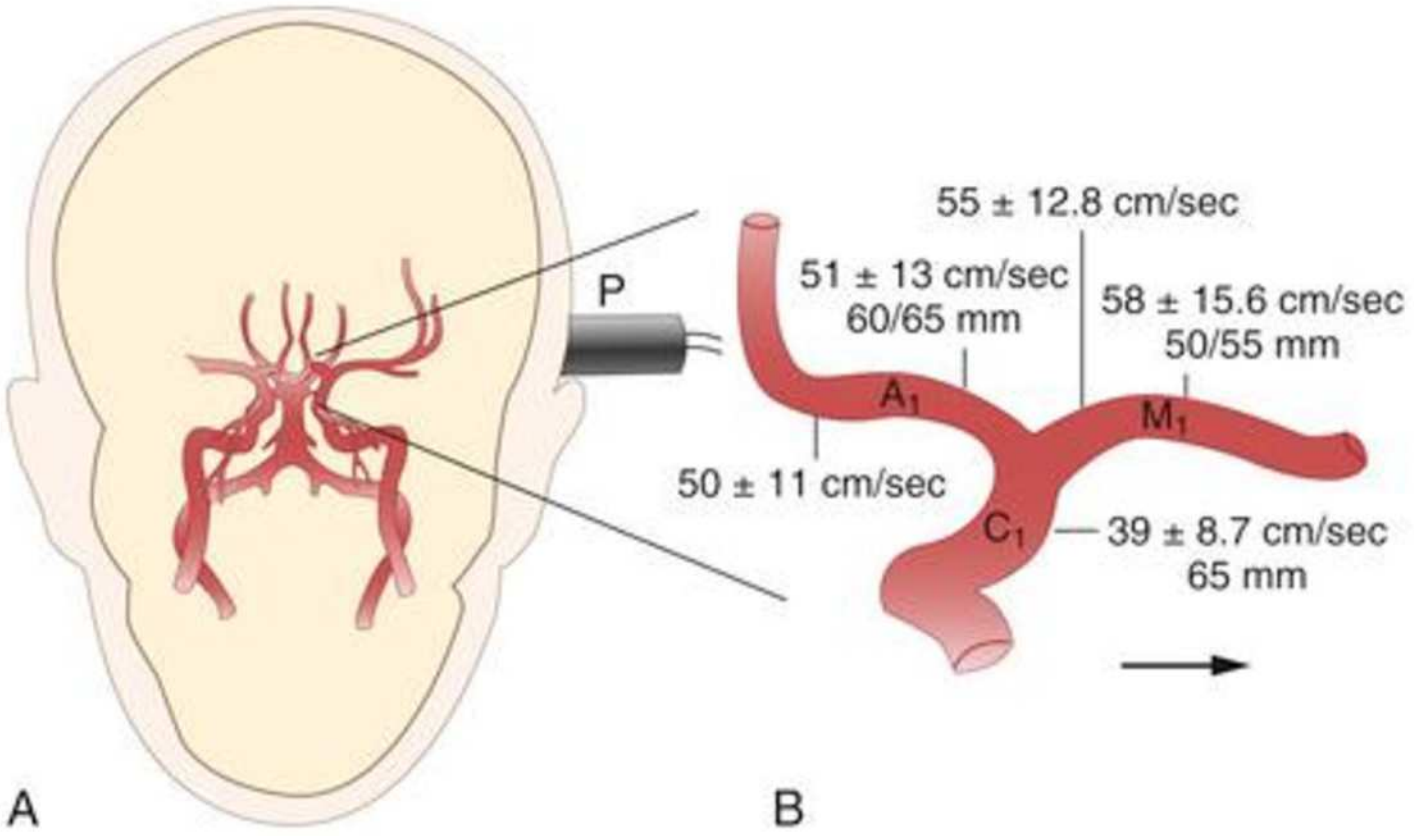


Figure 6 Transcranial Doppler wave form demonstrating an emboli.

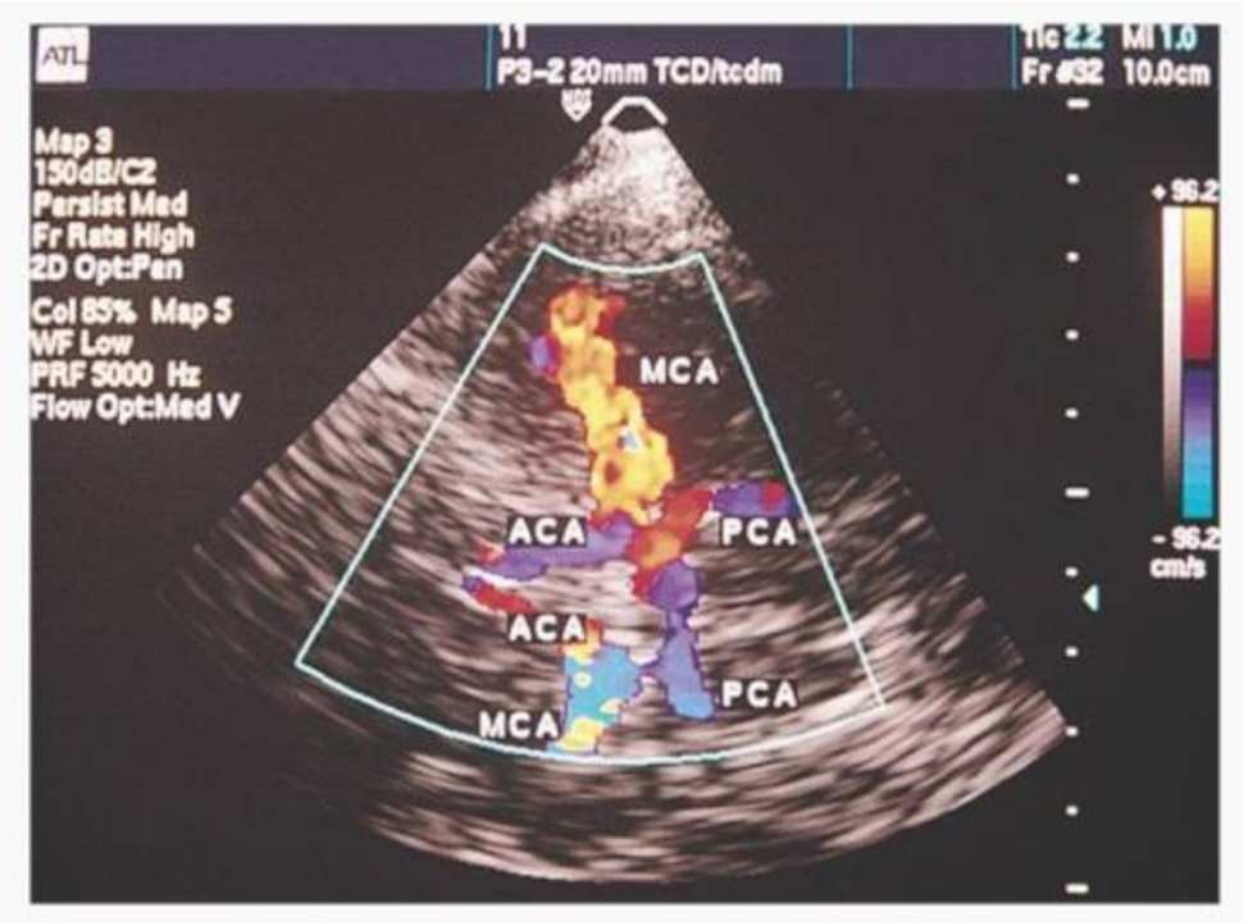
Transtemporaalne aken



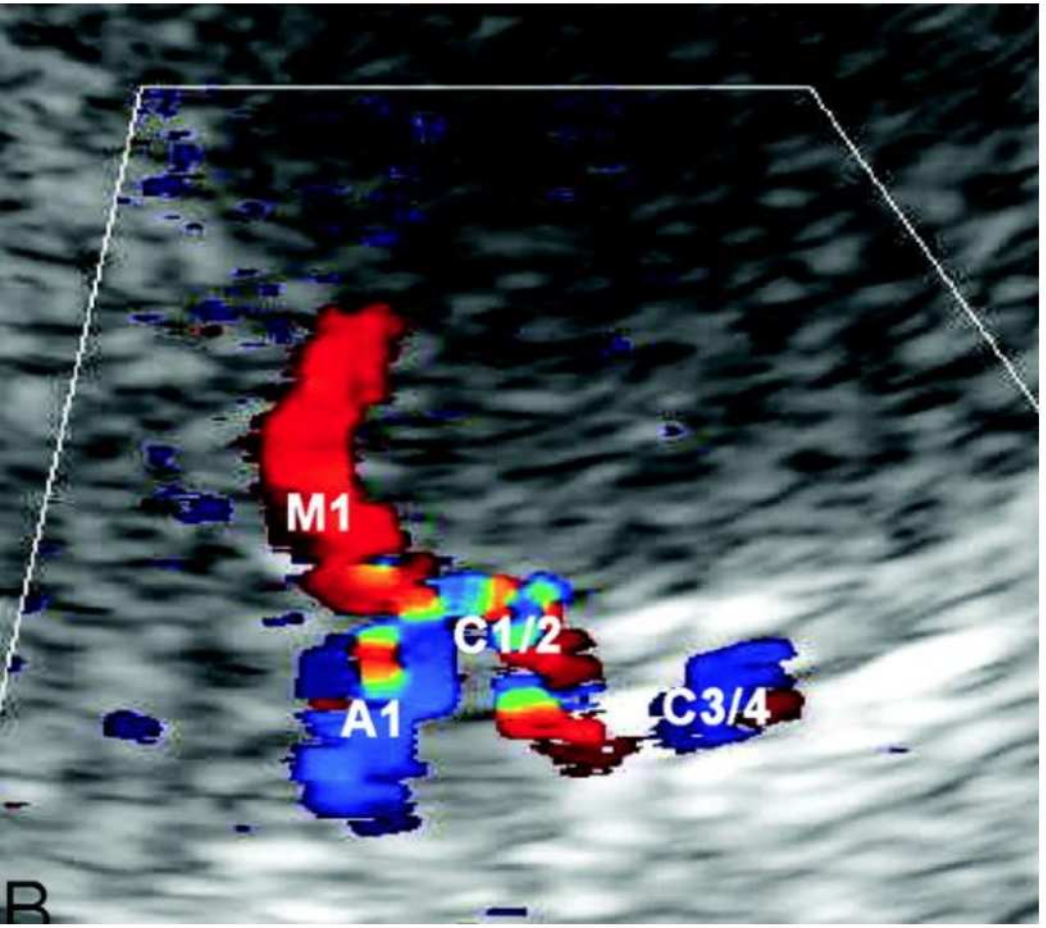
Transtemporaalne aken

- ICA bifurkatsiooni koht, MCA ja ACA (tavaliselt 6cm sügavusel)
- MCA
- - asub tavaliselt 3-6cm sügavusel
- - vool anduri suunas
- ACA
- - asub 6,5 – 8cm sügavusel
- - vool andurist eemale (aknas paikneb anterosuperioorsel)
- PCA
- - 5,5 – 7cm sügavusel
- - aknas paikneb posteroinferioorsel

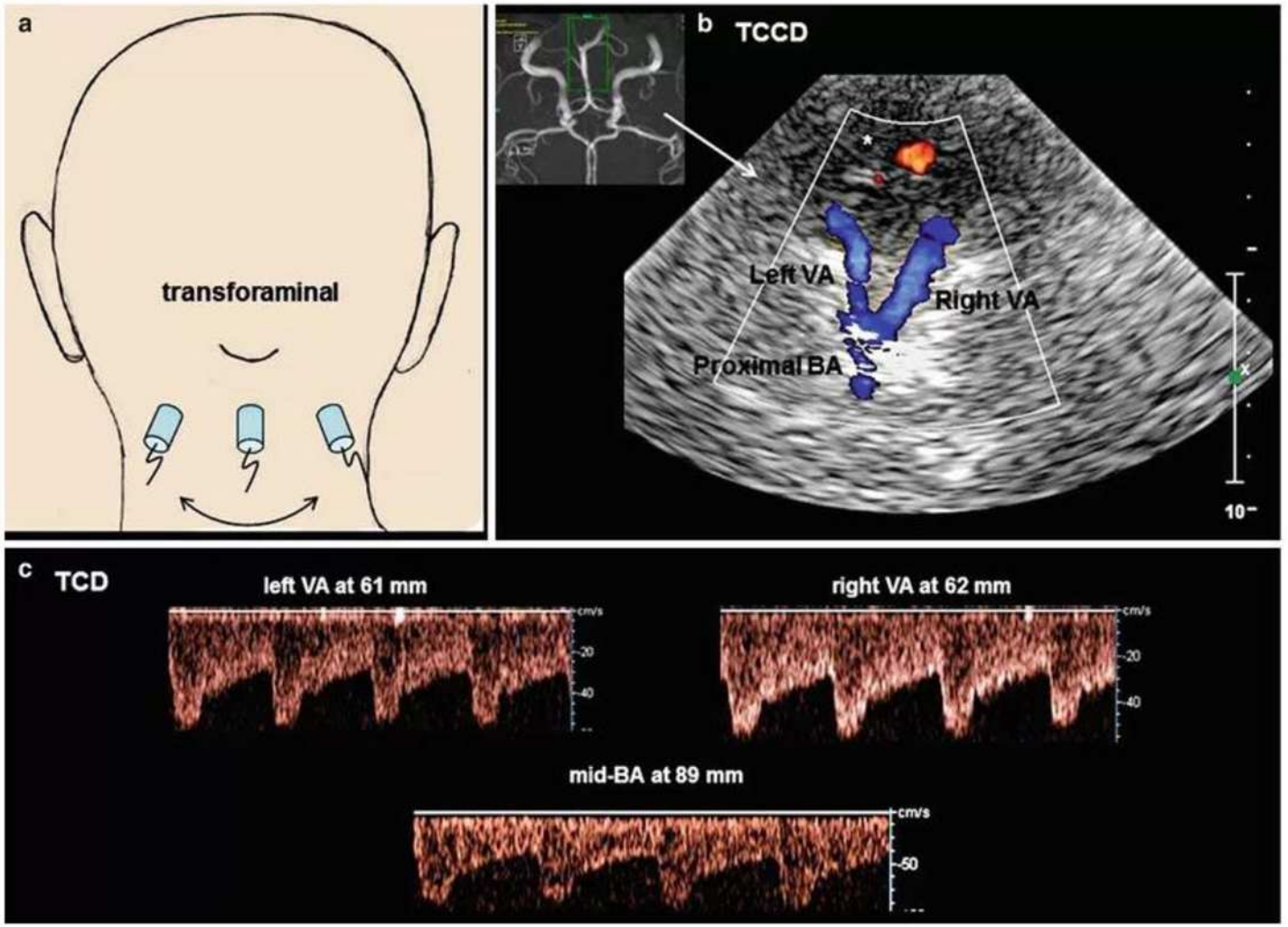
Transtemporaalaken



Trantemporaalne aken



Transforaminaalne aken

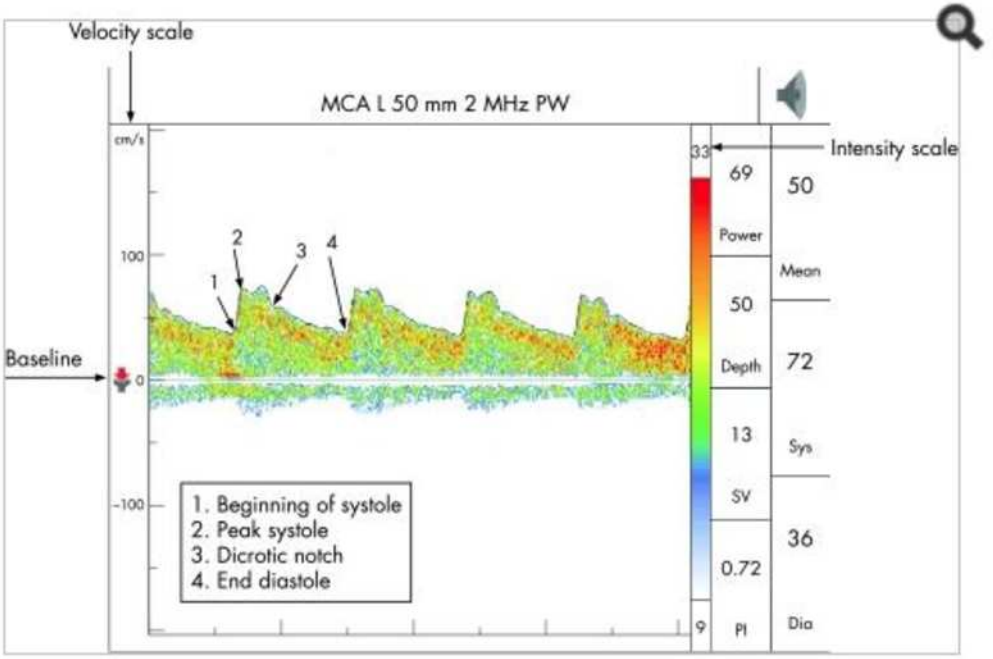


Willise ringi arterite normaalsed voolukiirused

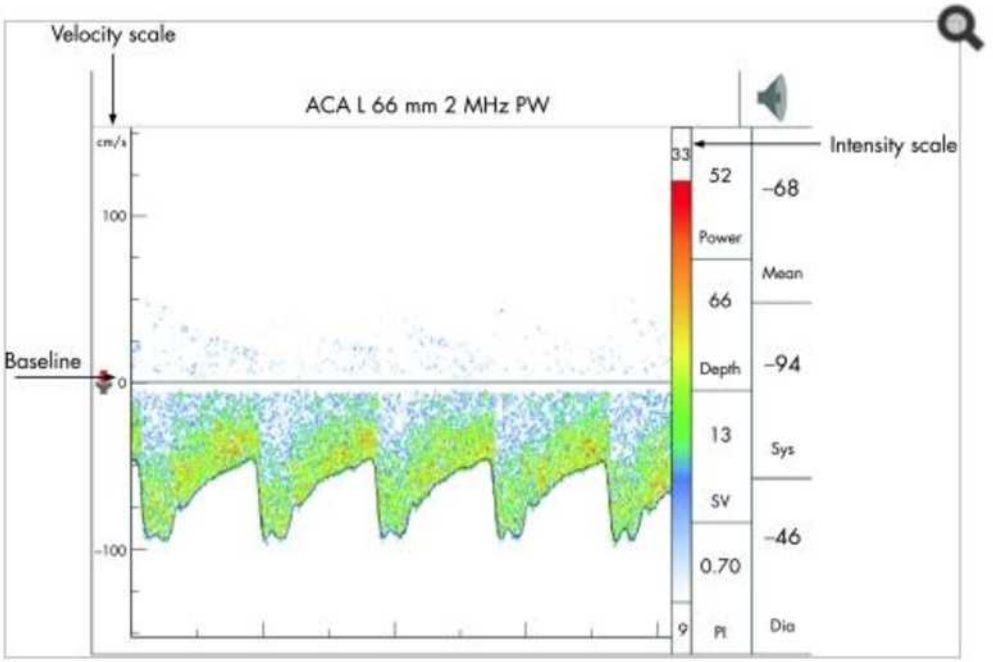
Artery	Depth (mm, adults)	Direction	Childrena	Adults
M2 MCA	30–45	Bidirectional	<170 cm/s	<80 cm/s
M1 MCA	45–65	Toward	<170 cm/s	<80 cm/s
A1 ACA	62–75	Away	<150 cm/s	<80 cm/s
A2 ACA	45–65	Toward	N/A	<80 cm/s
ICA siphon	60–65	Bidirectional	<130 cm/s	<70 cm/s
OA	40–60	Toward	Variable	Variable
PCA	55–70	Bidirectional	<100 cm/s	<60 cm/s
BA	80–100+	Away	<100 cm/s	<60 cm/s
VA	45–80	Away	<80 cm/s	<50 cm/s

Voolukõverad

- MCA



- ACA


Velocity scale
ACA L 66 mm 2 MHz PW
Intensity scale
cm/s
100
0
-100
Baseline
33
9
52
Power
66
Depth
13
SV
0.70
PI
-68
Mean
-94
Sys
-46
Dia

TCD akuutse isheemilise infarkti puhul

- Efektiivne eeskätt ICA ja MCA patoloogiate puhul (spetsiifilisus 83%, sensitiivsus 94%). BA ja VA oklusioonide puhul väheinformatiivne
- 90% angiograafiliselt diagnoositavaid oklusioone saab diagnoosida ka TCD abil 5t jooksul peale infarkti teket
- Saab hinnata rekanalisatsiooni (voolu teke okluseeritud arteris)
- Abiks prognoosi ja trombolüüsi effektiivsuse hindamisel

Stenoosi või okklusiooni tunnused

Box 3: Signs of stenosis and occlusion

Primary signs of stenosis

- Focal increase in mean flow velocity at the site of luminal narrowing

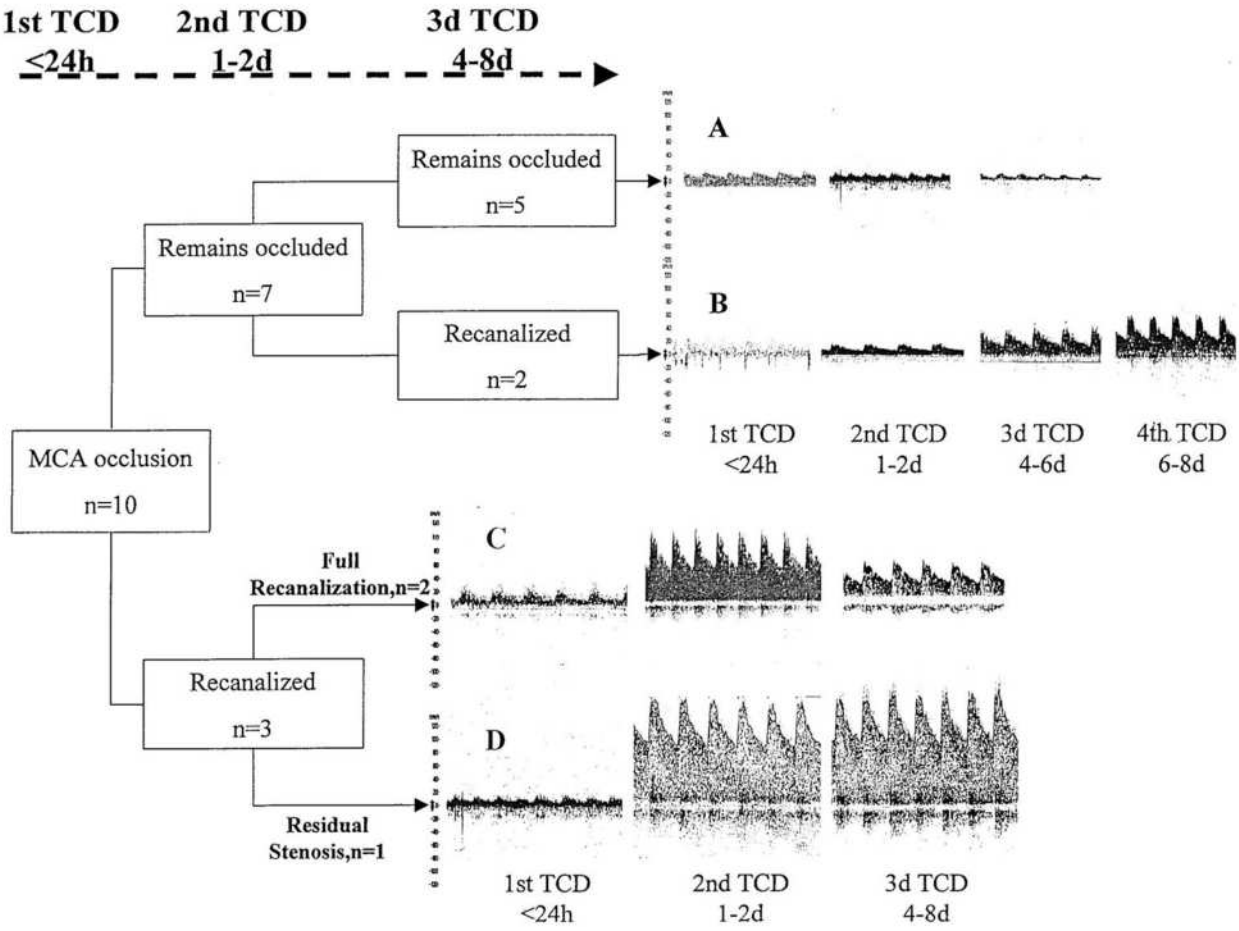
Secondary signs of stenosis

- Decreased velocity and increased pulsatility upstream from the lesion
- Abnormal flow immediately downstream from the lesion

Signs of occlusion

- Absence of signal from artery
- Sonographic evidence of collateral flow

MCA okklusiooni hindamine



Ekstrakraniaalsed veresoonte anomaaliad

- Aitab hinnata ICA stenoosi hemodünaamilist olulisust TIA puhul
- Sama poole voolukiirus väheneb, vastaspoole voolukiirus suureneb
- Sama poole ACA-s reversiivne vool

Parema ICA ekstrakraniaalse osa stenoos

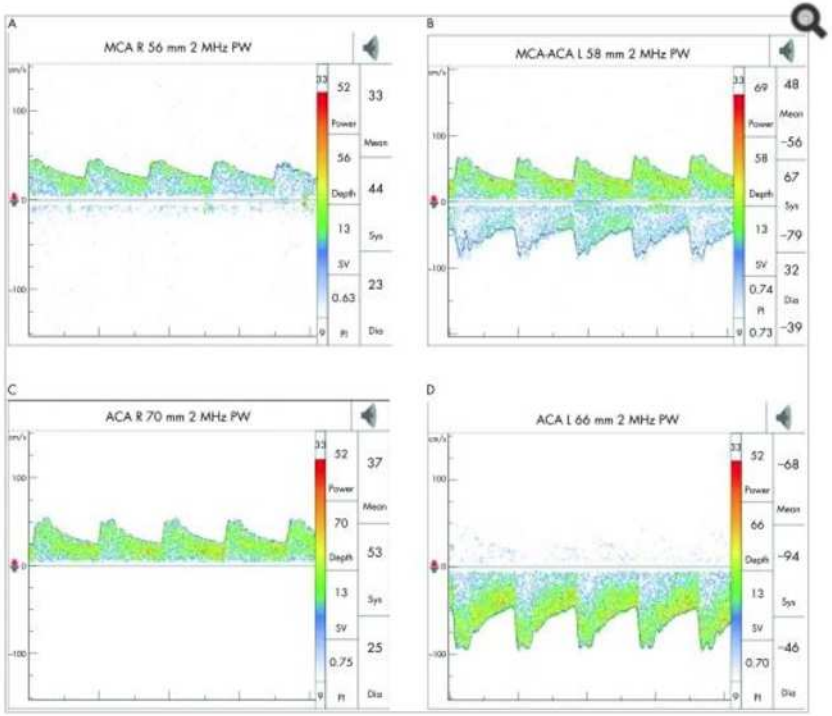


Figure 5 Effect of extracranial internal carotid artery (ICA) stenosis on cerebral haemodynamics (patient had high grade ste proximal right ICA). (A) Decrease in mean flow velocity of right (ipsilateral) middle cerebral artery (MCA). (B) Normal flow (contralateral) MCA with increased flow in left (contralateral) anterior cerebral artery (ACA) (due to collateral flow). (C) Rev in right (ipsilateral) ACA. (D) Increased flow in left (contralateral) ACA.

Infarkti riski hindamine südamerikkega patsientidel (parem-vasak šunt)

- Kasutatakse kontrastainet (gaasi osakesed)
- Otsitakse MES signaali
- Negatiivne: ei ole mikroemboleid
- Madala astme šunt: 1-10 ME
- Keskmise astme šunt: > 10 ME
- Kõrge astme šunt: „kardina” efekt, ME ei saa kokku lugeda

Isheemilise infarkti prognostika

- 6t peale infartkti ja normaalne TCD = hea prognoos
- Juhul kui 12t jooksul peale MCA oklusiooni selle voolukiirus on endiselt <30cm/s – prognosis pessima
- Mikroembolid

TCD ja SAH. Vasospasm

- 30% SAH patsientidest 3-4. päeval tekkib vasospasmi oht. See suureneb kuni 11-17. päevani ja siis hakkab järk-järgult langema
- 25% patsientidest jäävad vasospasmi järgselt neuroloogilise defitsiidiga
- Etioloogia ebaselge
- Kuldne standart – angiograafia.
- Esinev tavaliselt MCA-s

TCH ja vasospasm

- Võimaldab dünaamilist vasosapsmi monitooringut
- Selle alusel võib alustada 3H teraapiat (hüpotoonia, hemodilutsioon ja hüpervoleemia)
- Või olla näidustuseks farmakoloogiliseks vasodilatatsiooniks
- Võib olla näidustuseks balloonangioplastikaks
- Spetsiifilisus 72-99% ning sensitiivsus 67-88%, avastab kuni 33% angiograafiliselt kinnitatud vasospasmidest
- ACA ja PCA spetsiifilisus ja sensitiivsus on siiski oluliselt madalam, võrreldes MCA vasospasmiga

Vasospasmi kriteeriumid

Table 3: Grading of vasospasm severity [31, 32].

Degree of MCA or ICA vasospasm	MFV (cm/s)		LR
Mild (<25%)	120–149	A	3–6
Moderate (25–50%)	150–199	N	3–6
Severe (>50%)	>200	D	>6
Degree of BA vasospasm	**MFV (cm/s)**		**Modified LR**
May represent vasospasm	70–85	A	2–2.49
Moderate (25–50%)	>85	N	2.5–2.99
Severe (>50%)	>85	D	>3

Table 10.3 Sloan's optimized criteria for grading vasospasm (VSP)

Artery/MFV	Possible VSP	Probable VSP	Definite VSP
ICA	>80	>110	>130
ACA	>90	>110	>120
PCA	>60	>80	>90
BA	>70	>90	>100
VA	>60	>80	>90

Vasospasm

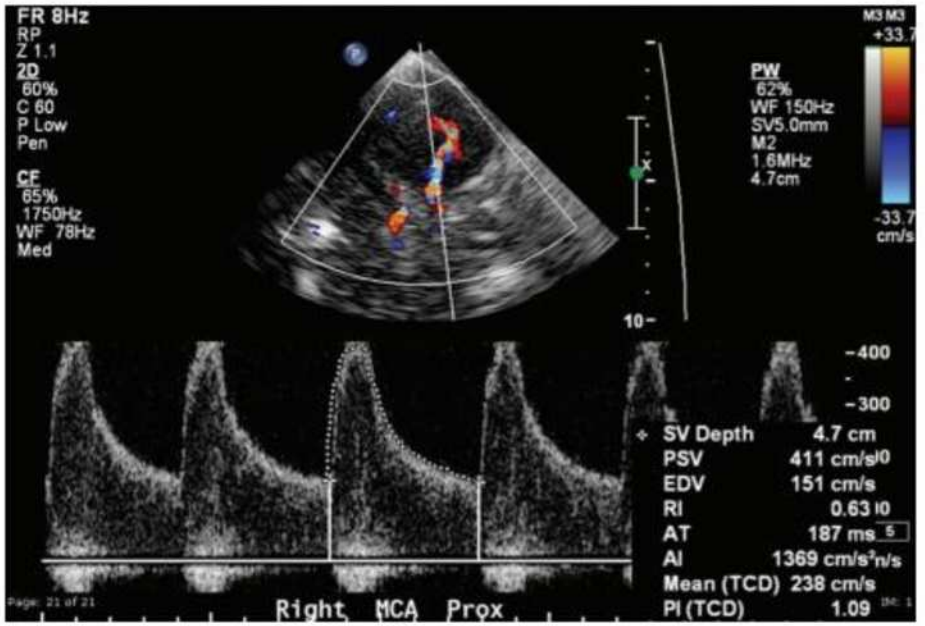


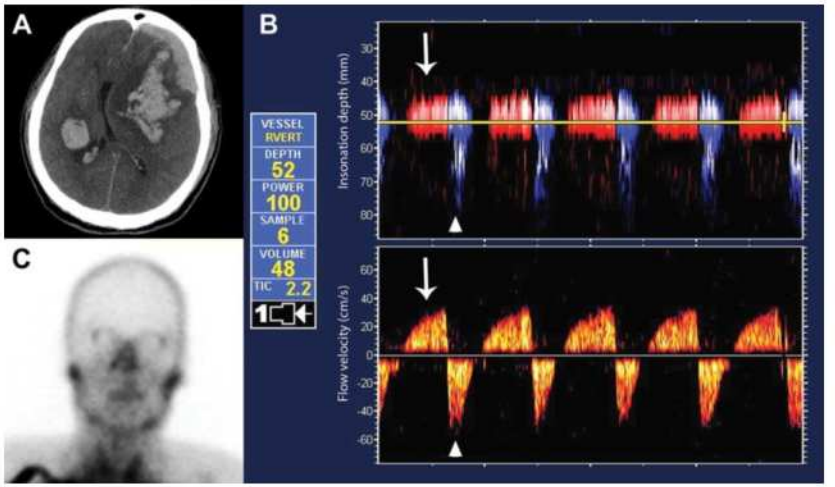
FIGURE 3: A 70-year-old woman with SAH. TCD demonstrates an increased PSV and MFV in the right MCA, consistent with severe vasospasm.

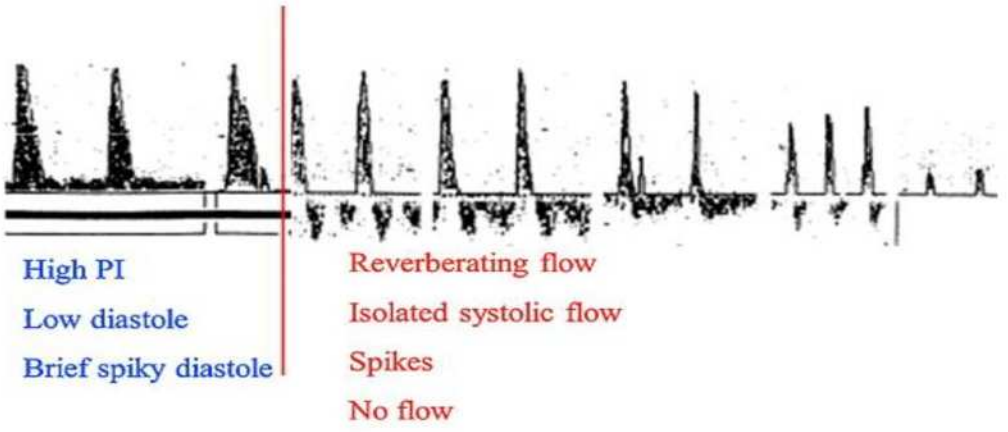
Ajusurm

- Diagnoositakse vastaval protokollile, kus TCD ja muud radioloogilised uuringud on hetkel abistava tähendusega
- Ajuverevarustuse seiskus TCD-l diagnoositakse juhul kui vähemalt kahel uuringul mille vahel on vähemalt 30 min BA, bilateraalselt ICA ja bilateraalsel MCA on jälgitavad tsirkulaarsele seiskusele iseloomulikud muutused.

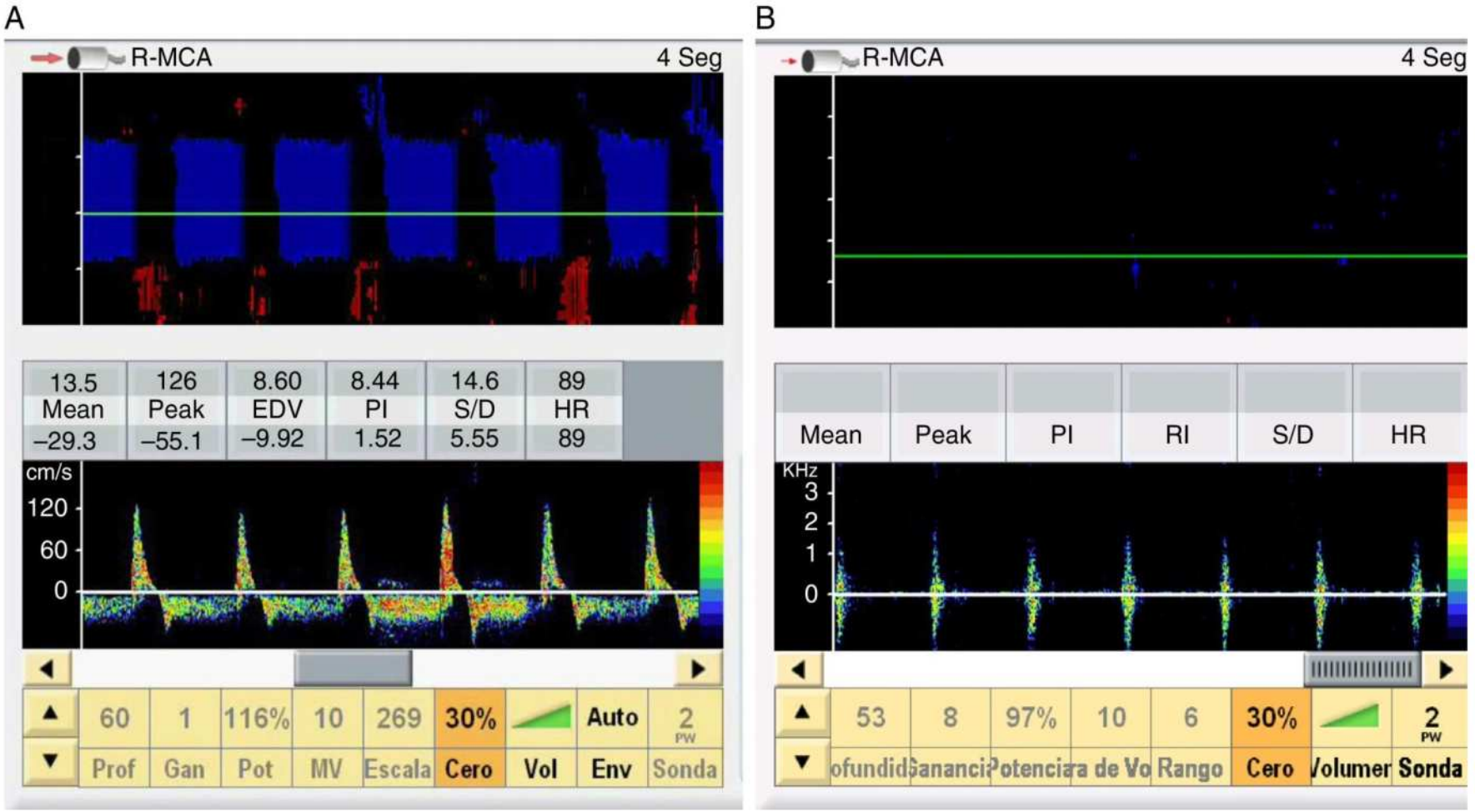
Tserebraalne tsirkulatorne seiskus

- Ostsilleeruv verevoolukõver
- Väiksed süstoolsed piigid (<200ms ja väiksemad kui 50cm/s) diastoolse voolu puudumisega
- Verevoolu puudumine





Ajusurm

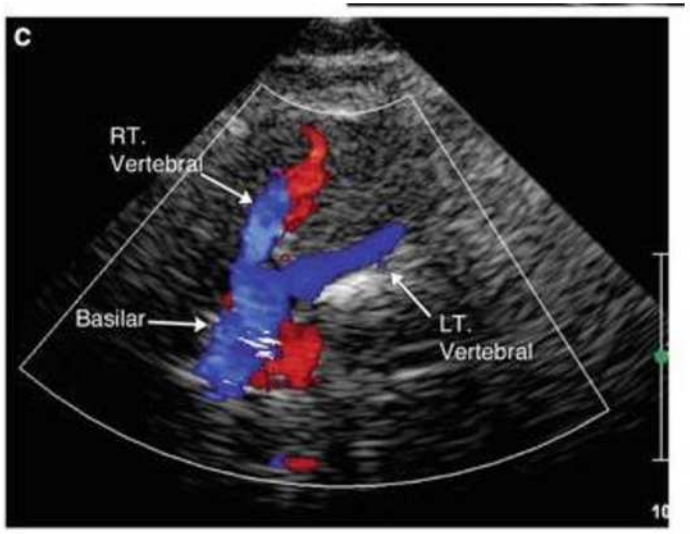

A
R-MCA
4 Seg
13.5 126 8.60 8.44 14.6 89
Mean Peak EDV PI S/D HR
–29.3 –55.1 –9.92 1.52 5.55 89
cm/s
120
60
0
60 1 116% 10 269 30% Auto 2 PW
Prof Gan Pot MV Escala Cero Vol Env Sonda
B
R-MCA
4 Seg
Mean Peak PI RI S/D HR
KHz
3
2
1
0
53 8 97% 10 6 30% 2 PW
Cero Volumen Sonda

TCD endarterektoomia ajal

- Saab monitoorida MCA voolu ICA sulgemise ajal selleks, et hinnata voolu adekvaatsust
- Jälgitakse mikroembolite suhtes
- Postoperatiivset saab avastada hüperperfusiooni fenomeeni

„Subclavian steal" sündroom

- A. subclavia oklusiooni korral tekkiv retrograadne vool a. vertebralises või a. pectoralises.
- Kasutatakse transforamenaalset akent
- Saab visualiseerida vertebraal ja basilaarartereid
- Voolukiirus ajuarterites väheneb



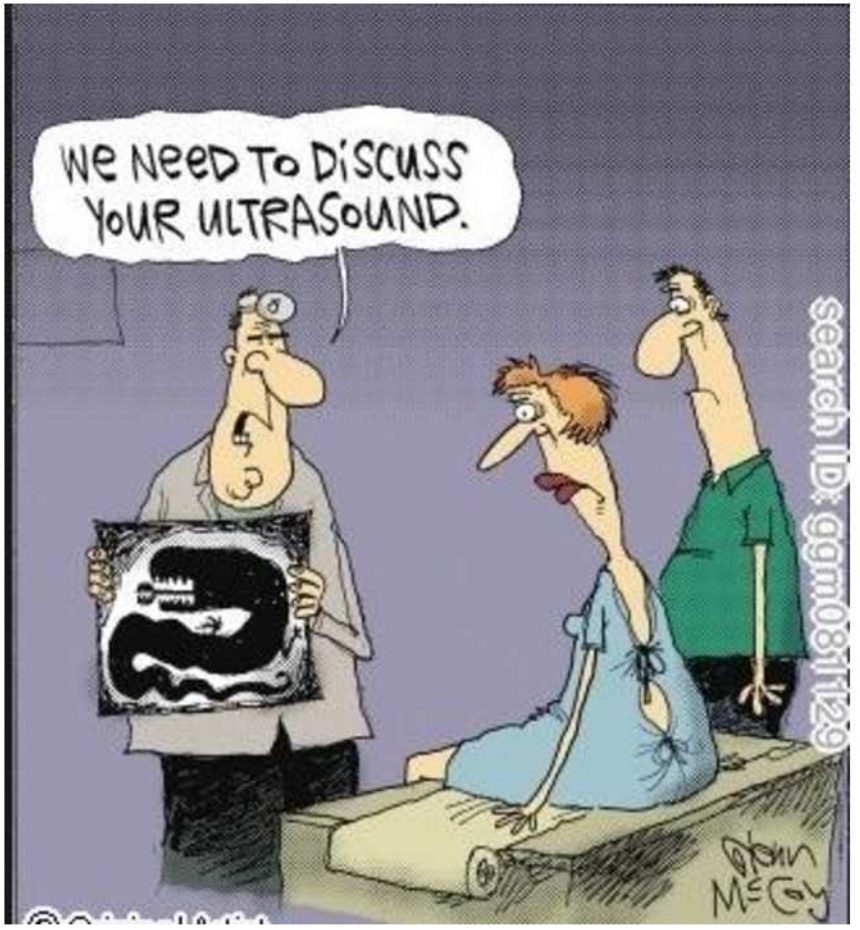
Sirprakuline aneemia

- Kõrgem risk saada peaajuinfarkti anatoomiliste ja füsioloogiliste iseärasuste tõttu (stenoosid, verehüüvete teke, endoteeli kahjustus)
- Hüperdünaamiline verevool (CBF-V >200cm/s) tõstab peaajuinfarkti riski, kuid sageli jääb lastel asümptomaatiliseks
- Hinnatakse bilateralselt MCA, bifurkatsioon, distal ICA, ACA, PCA, and BA
- Vereülekanded vähendavad infarkti riski

Kokkuvõte

- TCD on suhteliselt odav, kättesaadav ja mitteinvasiivne uuringumeetod, millega teoreetiliselt saab palju informatsiooni
- TCD kasutust piirab inimese anatoomilised iseärasused
- TCD ei pruugi olla täpsem, kui teised invasiivsed või mitteinvasiivsed radioloogilised uuringumeetodid
- On operaatorsõltuv
- Aeganõudev protseduur

Tänan


WE NEED TO DISCUSS YOUR ULTRASOUND.
search ID: ggm08f129
JOHN McCOY

kirjandus

- Role of transcranial Doppler ultrasonography in stroke (Postgrad Med J. 2007 Nov; 83(985): 683–689.)
- Transcranial doppler: Technique and common findings (Ann Indian Acad Neurol. 2013 Apr-Jun; 16(2): 174–179.)
- Transcranial Doppler Ultrasound: Technique and Application (Semin Neurol. 2012 Sep; 32(4): 411–420.)
- Transcranial Doppler Ultrasound: A Review of the Physical Principles and Major Applications in Critical Care (International Journal of Vascular Medicine Volume 2013 (2013), Article ID 629378, 13 pages)
- Transcranial Doppler ultrasonography of the basilar artery in patients with retrograde vertebral artery flow (Journal of Vascular Surgery Volume 48, Issue 4, October 2008, Pages 859-864)
- A review of subclavian steal syndrome with clinical correlation (Med Sci Monit. 2012; 18(5): RA57–RA63.)
- Hemodynamic Studies in Early Ischemic Stroke (Stroke May 2002, Volume 33, Issue 5)
- Collateral Variations in Circle of Willis in Atherosclerotic Population Assessed by Meansof Transcranial Color-Coded Duplex Ultrasonography.(Stroke. 2000;31:1656-1660)
- Transcranial Doppler Ultrasound: A Review of the Physical Principles and Major Applications in Critical Care (International Journal of Vascular Medicine Volume 2013, Article ID 629378)
- Use of Transcranial Doppler Ultrasound for Diagnosis of Brain Death in Patients with Severe Cerebral Injury (Med Sci Monit, 2016; 22: 1910-1915)
- Transcranial Doppler ultrasound in the diagnosis of brain death. Is it useful or does it delay the diagnosis? (Med Intensiva. 2015;39(4):244---250)
- Transcranial Doppler monitoring in subarachnoid hemorrhage: a critical tool in critical care (Canadian J Anesth 55: 2008)
- Transcranial Doppler Ultrasonography for Diagnosis of Cerebral Vasospasm After Aneurysmal Subarachnoid Hemorrhage: Mean Blood Flow Velocity Ratio of the Ipsilateral and Contralateral Middle Cerebral Arteries (Neurosurgery volume 69,| number 4 | october 2011).