

TCD and stroke

Background:

Unlike other imaging modalities, cerebrovascular ultrasound provides real-time information about the blood flow in addition to the hemodynamic changes as a result of various physiological as well as pathological states.

Intracranial atherosclerotic disease is associated with a high risk of stroke. High flow velocities (FV) in TCD can predict stroke. It is an urgent subject of research to find cut-off points that provide high sensitivity and specificity.

Evaluation of posterior circulation with single-gate transcranial Doppler (TCD) is technically challenging and yields lower accuracy parameters in comparison to anterior circulation vessels.

Literature:

Velocity criteria for intracranial stenosis revisited: an international multicenter study of transcranial Doppler and digital subtraction angiography.

Author	(Zhao, Barlinn, u. a., 2011)
Content/Summary	high sensitivity of TCD to detect cerebral stenosis (DSA was used to control these results). SONIA criteria showed 91% sensitivity for stenosis >70% when different criteria are combined.
Comment	A total of 102 patients with intracranial atherosclerotic disease (age 57±13 years; 72% men; median National Institutes of Health Stroke Scale 3, interquartile range 6) provided 690 transcranial Doppler/digital subtraction angiography vessel pairs.
Doppler-device	??
Quantification	At laboratories with a standardized scanning protocol, SONIA mean flow velocity criteria remain reliably predictive of ≥50% stenosis. Novel velocity/ratio criteria for ≥70% stenosis increased sensitivity and showed good agreement with invasive angiography.

Role of diagnostic ultrasound in patient selection for stroke intervention.

Author	(V. K. Sharma u. a., 2011)
Content/Summary	Transcranial Doppler ultrasonography (TCD) is the only non-invasive examination that provides a reliable evaluation of intracranial blood flow patterns in real-time, adding physiological information to the anatomical information obtained from other neuroimaging modalities.
Comment	
Doppler-device	None / Review
Quantification	Advanced applications of cerebrovascular ultrasonography have become an integral part of the armamentarium of stroke neurologists for evaluating stroke mechanisms, plan and monitor treatment and determine prognosis.

An unhappy patient following successful sonothrombolysis in vertebrobasilar thrombosis: dilemma with final diagnosis.

Author	(Vijayan u. a., 2011)
Content/Summary	Therapeutic route and the time window for systemic thrombolysis in acute settings remain uncertain. We describe a case of severe acute ischemic stroke due to vertebrobasilar thrombosis who achieved rapid arterial recanalization and remarkable clinical recovery during ultrasound enhanced intravenous thrombolysis, initiated at 4.5 hours after the symptom-onset.
Comment	Case report
Doppler-device	DWL
Quantification	Authors believe that, in this case, ultrasound exposure of the VB arteries through the transforaminal window might have resulted in the transmission of higher energy to the clot, contributing to the faster recanalization induced by IV-tPA.

Validation of transcranial Doppler with magnetic resonance angiography in acute cerebral ischemia.

Author	(Boddu u. a., 2011)
Content/Summary	Twenty-two (14.6%) patients were excluded due to absent temporal acoustic windows. Middle cerebral artery TCD PSV values of >140 cm/s and >180 cm/s were found to predict a >50% and >70% focal stenosis, respectively. Optimal cut-off PSV values for other major proximal intracranial arteries were also established.
Comment	One hundred and fifty patients (74% males; mean age 53 years) underwent neurovascular evaluation with TCD and MRA.
Doppler-device	Multi-Dop B+, DWL
Quantification	TCD performed in our laboratory shows satisfactory agreement with TOF-MRA in diagnosis and grading of proximal intracranial stenosis in patients with acute cerebral ischemia.

Novel parameter for the diagnosis of distal middle cerebral artery stenosis with transcranial Doppler sonography.

Author	(Ahn u. a., 2010)
Content/Summary	The M2/M1 ratio was significantly higher in the M2 stenosis group (1.10 versus 0.86, $p < 0.001$). Sensitivity and specificity for M2 stenosis were most satisfying when the M2/M1 ratio of 0.97 was adopted as the cutoff value. Diagnostic yield of the M2/M1 ratio was better than MFV or asymmetry index.
Comment	Consecutive patients who underwent TCD and MRA were included. Based on MRA, M2 stenosis was defined as >50% narrowing beyond the bifurcation area. TCD index of the M2/M1 ratio was defined as the ratio between the mean flow velocity (MFV) obtained at a depth of 30-44 mm (M2) and a depth of 45-65 mm (M1)
Doppler-device	Pioneer TC-4040, EME, Uberlingen, Germany
Quantification	M2/M1 ratio predicts stenosis in M2 better than absolute velocity.

Detection of the siphon internal carotid artery stenosis: transcranial Doppler versus digital subtraction angiography.

Author	(You u. a., 2010)
Content/Summary	Twenty-nine patients were diagnosed with SICA stenosis or occlusion on TCD. Fourteen patients had abnormal TCD findings that were not confirmed by DSA. One patient with normal TCD but DSA showed mild (40%) stenoses. Accuracy parameters for TCD were as follows: sensitivity = 96.7% (95% confidence interval [CI]= 80.9-99.8), specificity = 93.9% (95% CI = 89.9-96.4), PPV = 65.9% (95% CI = 50.0-79.1), NPV = 99.6% (95% CI = 97.2-1.0). Most false-positive patients (11 of 15 patients) had other significant intracranial large arteries lesions.
Comment	A total of 145 patients with TCD and DSA performed were recruited. The SICA and other intracranial arteries were evaluated through transorbital and transtemporal acoustic window by TCD.
Doppler-device	EME TC-22, Nicolet, EME, Kleinostheim, Germany
Quantification	The criteria have limited but acceptable sensitivity and specificity in detecting SICA (ICA siphon) stenoses. Low PPV. Abnormal findings of siphon carotid on TCD require further clarification.

Yield of systematic transcranial Doppler in patients with transient ischemic attack.

Author	(Meseguer u. a., 2010)
Content/Summary	After 1-year follow-up on best preventive therapy, the incidence of recurrent vascular events (intracranial revascularization for TIA recurrence, stroke, myocardial infarction, and vascular death combined) was 7.0% in patients with intracranial narrowing or occlusion and 2.4% in those without (log-rank, $p = 0.007$)
Comment	Between January 2003 and December 2007, 1,881 patients were admitted to SOS-TIA clinic (a TIA clinic with around-the-clock access). Clinical and vascular assessment included TCD performed by a neurologist immediately after admission.
Doppler-device	Not named
Quantification	Immediate TCD examination on arrival at the TIA clinic is feasible and could help to identify patients at high risk of vascular events recurrence. This study supports a systematic intracranial vascular examination in the initial management of TIA. Recommendation to perform TCD regularly on admission of TIA patients.

The assessment value of transcranial Doppler sonography versus magnetic resonance angiography in vertebrobasilar stroke

Author	(Ghorbani u. a., 2010)
Content/Summary	TCD was only able to differentiate between stenotic and normal pattern and could not assist in the grading of stenosis. On the other hand, in acute vertebrobasilar stroke that TCD performed blindly without visualization of arteries and in a fixed depth it might have limited value in the grading of vertebrobasilar system stenosis.
Comment	Samples were patients with definite clinical diagnosis of vertebrobasilar stroke. For all patients brain MRI, MRA and TCD were performed during the first 48 hours of admission
Doppler-device	DWL
Quantification	TCD was only able to differentiate between stenotic and normal pattern and could not assist in the grading of stenosis.

End-diastolic velocity increase predicts recanalization and neurological improvement in patients with ischemic stroke with proximal arterial occlusions receiving reperfusion therapies.

Author	(A. V. Alexandrov u. a., 2010)
Content/Summary	EDV increase at the end of monitoring was higher in patients with favorable functional outcome at 3 months (13 + or - 13 cm/s versus 4 + or - 8 cm/s; P=0.021). After adjustment for potential confounders, including age, stroke risk factors, and baseline stroke severity, a 10-cm/s increase in EDV was independently associated with a 3-point decline in the National Institutes of Health Stroke Scale score at 24 hours from baseline (95% CI: 0 to 5; P=0.045).
Comment	36 patients
Doppler-device	Multigon, Yonkers, NY, and Spencer Technologies, Seattle, Washington
Quantification	A modest increase in the EDV as opposed to peak systolic velocity is associated with complete recanalization/reperfusion, early neurological improvement, and favorable functional outcome. Diastolic flow augmentation may represent a novel target for development of reperfusion therapies.

Role of transcranial Doppler ultrasonography in cerebrovascular disease.

Author	(Yeo und V. K. Sharma, 2010)
Content/Summary	
Comment	Review
Doppler-device	none
Quantification	We have reviewed various recent patents in addition to the diagnostic, therapeutic, as well as, prognostic applications of TCD in patients with cerebrovascular disease.

Transient basilar artery occlusion monitored by transcranial color Doppler presenting with a spectacular shrinking deficit: a case report.

Author	(Nicoletti u. a., 2010)
Content/Summary	case of a 79-year-old Caucasian Italian woman with a transient basilar occlusion monitored by transcranial Doppler, with subsequent recanalization and clinical shrinking deficit.
Comment	Case report
Doppler-device	???
Quantification	This is the first case of transient basilar occlusive disease diagnosed and monitored by transcranial Doppler. We believe that transcranial Doppler should be performed in all cases of unexplained acute loss of consciousness, in particular, if associated with signs of brainstem dysfunctions.

Diagnosis and quantitation of intracranial stenosis.

Author	(Edward Feldmann, 2009)
Content/Summary	The design and results of the SONIA trial are reviewed. The clinical utility of the SONIA approach and data set, in both clinical and research settings, is reviewed.
Comment	Good review of the SONIA trial
Doppler-device	None, Review
Quantification	Angiography, noninvasive tests and careful measurements remain crucial for the optimal management of patients with suspected intracranial atherosclerosis.

Residual flow at the site of intracranial occlusion on transcranial Doppler predicts response to intravenous thrombolysis: a multi-center study.

Author	(Saqqur u. a., 2009)
Content/Summary	Seventeen of 96 (17.7%) patients with TIBI 0, 41/124 (33.1%) with TIBI 1, 29/76 (38.2%) with TIBI 2 and 31/65 (47.7%) with TIBI 3 had achieved complete recanalization ($p < 0.001$). In the stepwise multiple linear regression models adjusting for baseline characteristics, the only 2 factors that independently associated with time to recanalization were: time to rt-PA treatment and the absent flow (TIBI 0) on baseline TCD. Absent flow (TIBI 0) was associated with a longer time of recanalization of 35.2 min (95% CI 0.3-70.1 min, $p = 0.048$).
Comment	A total of 361 patients with proximal arterial occlusion received intravenous rt-PA at 137.4 +/- 36 min (median NIHSS 16). Mean age 69 +/- 13, women
Doppler-device	
Quantification	The pretreatment residual flow at intracranial occlusion predicts the likelihood of complete recanalization, time of recanalization and long-term outcome. No detectable residual flow indicates the least chance to achieve recanalization and recovery with systemic thrombolysis and may support an early decision for combined endovascular rescue.

Use of Emergency department transcranial Doppler assessment of reperfusion after intravenous tPA for ischemic stroke.

Author	(Phillips u. a., 2008)
Content/Summary	TCD is a feasible assessment tool for use in the emergency department to aid in diagnosis and to guide treatment decisions in patients with acute ischemic stroke, including those not responding to IV-tPA therapy.
Comment	Case report
Doppler-device	??
Quantification	TCD may help to guide clinical treatment

Clinical-sonographic index (CSI): a novel transcranial Doppler diagnostic model for middle cerebral artery stenosis.

Author	(Jung und Lee, 2008)
Content/Summary	CSI might be useful to enhance diagnostic accuracy.
Comment	One hundred and seven patients (M:F = 53:54, age: 61.6 +/- 11.6 years), and 100 control subjects (M:F = 49:51, age: 54.9 +/- 14.5 years) were included. Clinical-sonographic index (CSI) model was built with significant parameters by multivariate logistic regression analysis.
Doppler-device	???
Quantification	CSI as a new calculated value to detect stenosis.

Transcranial Doppler ultrasonography-directed intravenous glycoprotein IIb/IIIa receptor antagonist therapy to control transient cerebral microemboli before and after carotid endarterectomy.

Author	(van Dellen u. a., 2008)
Content/Summary	The median (range) rate of microemboli decreased from 22 (4-260) per h before surgery and 81 (44-216) per h after surgery to 0 (0-9) per h in both groups (P < 0.001, Mann-Whitney U test). This occurred rapidly (preoperative median 30 min; postoperative median 45 min) and was well tolerated in all patients, with no serious adverse effects. Cerebral microemboli were controlled by tirofiban both before and after CEA. Further study is required to compare the relative efficacy of tirofiban and dextran.
Comment	Thirty-three patients were treated with tirofiban
Doppler-device	PC Dop 842 (SciMed, Bristol, UK)
Quantification	TCD to guide and control anti-plateled therapy.

Validation of transcranial Doppler with CT angiography in cerebral ischaemia: a preliminary pilot study in Singapore.

Author	(Rathakrishnan u. a., 2008)
Content/Summary	Compared with 21 segments of significant stenosis on CTA, TCD showed 16 true-positive, 3 false-positive and 5 false-negative results (sensitivity: 76.2%, positive predictive value: 84.2%). In 3 cases, TCD showed findings complementary to CTA (real-time embolisation, collateral flow patterns, evidence of distal M2 branch occlusion).
Comment	Only 15 patients (12 men, mean age 61 +/- 15years)
Doppler-device	Companion III, Nicolet-Viasys
Quantification	Low PPV but provides additional information. TCD in our neurovascular laboratory shows a satisfactory agreement with cranial CTA in evaluating patients with cerebral ischaemia. TCD can provide additional real-time dynamic findings complementary to information provided by CTA.

Applications and advantages of power motion-mode Doppler in acute posterior circulation cerebral ischemia.

Author	(Tsvigoulis u. a., 2008)
Content/Summary	PMD-TCD yields a satisfactory agreement with urgent brain angiography in the evaluation of patients with acute posterior circulation cerebral ischemia. PMD display can depict flow signatures that are complimentary to and can increase confidence in standard single-gate TCD spectral findings. Compared with angiography, PMD-TCD showed 17 true-positive, 8 false-negative, 6 false-positive, and 182 true-negative studies in posterior circulation vessels (sensitivity 73% [55% to 91%], specificity 96% [93% to 99%], positive predictive value 68% [50% to 86%], negative predictive value 95% [92% to 98%], accuracy 93% [90% to 96%]).
Comment	A total of 213 patients (119 men; mean age 65+/-16 years; ischemic stroke 71%, transient ischemic attack 29%) underwent emergent neurovascular assessment.
Doppler-device	PMD-TCD (Spencer Technologies). Does DWL allow the same?
Quantification	PMD display can depict flow signatures that are complimentary to and can increase confidence in standard single-gate TCD spectral findings.

Noninvasive detection of diffuse intracranial disease.

Author	(V. K. Sharma u. a., 2007)
Content/Summary	After adjustment for stroke risk factors, transcranial Doppler findings of low mean flow velocities and high pulsatility index in a single vessel were independently associated with angiographically demonstrated diffuse single vessel intracranial disease, whereas low mean flow velocities/high pulsatility index in multiple vessels were related to multivessel intracranial disease (OR: 19.7, 95% CI: 4.8 to 81.2, P<0.001).
Comment	One hundred fifty-three patients (96 men, 76% white, age 62+/-15 years) had previous strokes (n=135) or transient ischemic attack (n=18)
Doppler-device	Spencer PMD 100 (Spencer Technologies, Inc)
Quantification	Diffuse intracranial disease may have a higher than expected frequency in a select stroke population and can be detected with noninvasive screening.

Role of transcranial Doppler ultrasonography in stroke.

Author	(Sarkar u. a., 2007)
Content/Summary	This article deals with the principles and technique of transcranial Doppler sonography. It gives a brief overview of its use in evaluation of intracranial steno-occlusive disease, subarachnoid haemorrhage, and extracranial diseases (including carotid artery disease and subclavian steal syndrome). The role of transcranial Doppler in detection of microembolic signals and evaluation of right to left shunts is also dealt with.
Comment	overview
Doppler-device	???
Quantification	Finally, its use in acute stroke is briefly outlined. Good to learn more about TCD in stroke easily.

Transcranial Doppler hemodynamic parameters and risk of stroke: the Rotterdam study.

Author	(Bos u. a., 2007)
Content/Summary	Risk of stroke (n=122) and ischemic stroke (n=89) increased with increasing middle cerebral artery flow velocity. The side of highest flow velocity was not associated with the side of stroke. We found no associations between vasomotor reactivity and risk of stroke.
Comment	To explore the association between transcranial Doppler hemodynamic parameters and the risk of stroke in the general population.
Doppler-device	????
Quantification	Risk of stroke increased strongly with increasing middle cerebral artery flow velocity as measured with transcranial Doppler in the general population.

The Stroke Outcomes and Neuroimaging of Intracranial Atherosclerosis (SONIA) trial.

Author	(E Feldmann u. a., 2007)
Content/Summary	Both transcranial Doppler ultrasound and magnetic resonance angiography noninvasively identify 50 to 99% intracranial large vessel stenoses with substantial negative predictive value. The Stroke Outcomes and Neuroimaging of Intracranial Atherosclerosis trial methods allow transcranial Doppler ultrasound and magnetic resonance angiography to reliably exclude the presence of intracranial stenosis. Abnormal findings on transcranial Doppler ultrasound or magnetic resonance angiography require a confirmatory test such as angiography to reliably identify stenosis.
Comment	SONIA enrolled 407 patients at 46 sites in the United States. SONIA standardized the performance and interpretation of TCD, MRA, and angiography. Study-wide cutpoints defining positive TCD/MRA were used. Hard copy TCD/MRA were centrally read, blind to the results of angiography.
Doppler-device	multiple
Quantification	SONIA criteria allow detection of intracranial stenosis reliably.

Validation of transcranial Doppler with computed tomography angiography in acute cerebral ischemia.

Author	(Tsivgoulis u. a., 2007)
Content/Summary	Compared with CTA, TCD showed 34 true-positive, 9 false-negative, 5 false-positive, and 84 true-negative studies (sensitivity 79.1%, specificity 94.3%, positive predictive value 87.2%, negative predictive value 90.3%, and accuracy 89.4%).
Comment	A total of 132 patients (74 men, mean \pm -SD age 63 \pm -15 years) underwent emergent neurovascular assessment with brain CTA and TCD
Doppler-device	PMD 100, Spencer Technologies; Ez-Dop, DWL Compumedics
Quantification	Beside TCD examination yields satisfactory agreement with urgent brain CTA in the evaluation of patients with acute cerebral ischemia. TCD can provide real-time flow findings that are complementary to information provided by CTA.

The accuracy of transcranial Doppler in the diagnosis of middle cerebral artery stenosis.

Author	(Navarro u. a., 2007)
Content/Summary	Using laboratory-specific variable mean flow velocity cutoffs, self-reported best accuracy results yield a mean weighted average sensitivity of 92%, specificity of 92%, PPV of 88% and NPV of 98% for 80 cm/s cutoff. For 100 cm/s cutoff, the sensitivities were 100%, specificity 97%, PPV 88% and NPV 100%.
Comment	Review of 6 randomized studies
Doppler-device	Multiple
Quantification	Although limited to few reports, this analysis demonstrates fair TCD performance against angiography. Since increasing velocity cutoffs do not yield decreasing sensitivity and increasing specificity, further studies are required to determine optimal velocity values and possibly other criteria such as velocity ratios to develop a screening test with balanced performance parameters.

Bedside emergency transcranial Doppler diagnosis of severe carotid disease using orbital window examination.

Author	(Saqqur u. a., 2005)
Content/Summary	Reversed OA (orbital artery) flow at 50 to 60 mm depth revealed high specificity (100%; confidence interval [CI], 97.6%-100.0%) and good sensitivity (75%; CI, 53.3%-90.2%) for identifying cICA occlusion or critical stenosis (>or=95%). Low pulsatility index (<1.2) and mean flow velocity (<15 cm/s) discriminated critical severe ICA stenosis or occlusion when OA flow was antegrade with good sensitivity (87.2%) and specificity (95.2%).
Comment	A total of 216 transorbital exams were performed in 117 patients
Doppler-device	???
Quantification	The reversed OA sign at 50 to 60 mm depth is very specific for identifying cICA occlusion or critical stenosis. When OA flow is antegrade, a low mean flow velocity or pulsatility index is also useful to identify cICA critical stenosis or occlusion. Was it actual the orbital artery? Or was it ICA in 50-60mm depth?

Summary:

TCD has a high specificity and lower sensitivity. The low positive predictive value (about 60-80 %) is one of the weaknesses of noninvasive ultrasound.

SONIA mean flow velocity seem to reliably predict $\geq 50\%$ stenosis.

Ratios predict stenosis better than absolute velocities.

Bedside TCD yields good accordance to CTA, MRA and DSA (gold-standard).

Residual flow on admission of stroke patients predicts better outcome than in those without residual flow.

Experts:

Sharma VK, Tsivgoulis G, Alexandrov AV, Nicoletti

Literature

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