

## **Monitoring and detection of vasospasm**

### **Background:**

Stroke is common after non-traumatic subarachnoid hemorrhage (aSAH). Transcranial Doppler ultrasound (TCD) monitoring is often employed during a period of at least 10 days to identify vasospasm and allow intervention to avoid infarction. One of its advantages is the noninvasive technique, which allows bedside examinations with little efforts and costs.

### **Literature:**

#### **Brain monitoring after subarachnoid hemorrhage: lessons learned**

Author	(Spiotta u. a., 2011)
Content/Summary	Some other invasive techniques are reviewed
Doppler-device	Not known
Quantification	Just additional information. More invasive techniques have been used.

#### **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.**

Author	(Nakae u. a., 2011)
Content/Summary	In patients with SAH the I/C (ratio of the ipsilateral to contralateral middle cerebral arteries) mBFV demonstrated a more significant correlation to vasospasm than the absolute mean flow velocity.
Doppler-device	Intra-View; Rimed, Ltd, Park Raanana, Israel
Quantification	Probably an improvement of sensitivity

#### **Detection and monitoring of vasospasm and delayed cerebral ischemia: a review and assessment of the literature.**

Author	(Washington und Zipfel, 2011)
Content/Summary	Transcranial Doppler is a useful screening tool for middle cerebral artery vasospasm, with less utility in evaluating other intracranial vessels.
Comment	Review of sensivity and specificity of TCD
Doppler-device	Not known
Quantification	TCD is worthful

### Progress in NIRS monitoring of cerebral blood flow.

Author	(Sakatani u. a., 2011)
Content/Summary	TRS (time-resolved near-infrared spectroscopy ) detected vasospasm by evaluating the CBO in the cortex and may be more sensitive than TCD, which assesses the blood flow velocity in the M1 portion. TRS may be useful for the diagnosis of ischemic events in stroke patients. Trans cranial Doppler (TCD) failed to detect vasospasm in 4 cases, whereas TR-NIRS could.
Comment	Article in Japanese 11 age-matched controls and 14 aneurysmal SAH patients
Doppler-device	Not known
Quantification	NIRS superior to TCD. Small patient sample size.

### Admission risk factors for cerebral vasospasm in ruptured brain arteriovenous malformations.

Author	(Chhor u. a., 2011)
Content/Summary	Cohort study describing the incidence and risk factors for cerebral vasospasm after brain AVM rupture. Larger studies are needed to investigate the significance of TCD-vasospasm and CI in these patients.
Comment	72 patients with ruptured brain AVM were included. TCD-VS occurred in 12 (17%) and CI in 6 (8%) patients.
Doppler-device	Not known
Quantification	New indication for TCD? Until today just SAH is the typical indication for vasospasm monitoring.

### Prolonged Transcranial Doppler Monitoring After Aneurysmal Subarachnoid Hemorrhage Fails to Adequately Predict Ischemic Risk.

Author	(Miller u. a., 2011)
Content/Summary	TCD identification of vasospasm after day 10 is rare. Stroke is more likely to result from poor detection than from brevity of TCD monitoring. Improved or alternative monitoring is needed to effectively identify ischemia and prevent stroke.
Comment	107 patients. Eligible patients were aged 18-85 years, presenting within 2 days of hemorrhage who had underwent TCD monitoring through post bleeding day 10.
Doppler-device	TCD („standard machine“) and TCCD
Quantification	Improved techniques are needed.

### Costs of vasospasm in patients with aneurysmal subarachnoid haemorrhage.

Author	(Chou u. a., 2010)
Content/Summary	Patients with subarachnoid hemorrhage and TCD-defined or symptomatic vasospasm incur higher inpatient costs and longer hospital stays than those without vasospasm.
Comment	„by the way“
Doppler-device	Not known
Quantification	Additional information

### Bedside monitoring of cerebral blood oxygenation and hemodynamics after aneurysmal subarachnoid hemorrhage by quantitative time-resolved near-infrared spectroscopy.

Author	(Yokose u. a., 2010)
Content/Summary	TR-NIRS detected vasospasm by evaluating the CBO in the cortex and may be more sensitive than TCD, which assesses the blood flow velocity in the M1 portion. The cerebral oxygen metabolism in SAH might be reduced by brain damage due to aneurysmal rupture.
Comment	
Doppler-device	Not known
Quantification	Same study as „Sakatani u. a., 2011“. Did they publish it twice?

### The role of transcranial Doppler ultrasonography in the diagnosis and management of vasospasm after aneurysmal subarachnoid hemorrhage.

Author	(Marshall, Nyquist, u. a., 2010)
Content/Summary	A review of the current indications, monitoring parameters, indices, and relevance of modern TCD technology is provided, as well as algorithms for the use of TCD ultrasonography in the management of patients with subarachnoid hemorrhage. Other current uses of TCD ultrasonography are also discussed in the setting of neurocritical care.
Comment	No access to the full-text article
Doppler-device	Not known
Quantification	a good summary

### Noninvasive imaging techniques in the diagnosis and management of aneurysmal subarachnoid haemorrhage.

Author	(Marshall, Kathuria, u. a., 2010)
Content/Summary	Although digital subtraction angiography is still considered the gold standard for the diagnosis of aSAH (and vasospasm), new and less invasive modalities are emerging including ultrasound, CT, CT angiography and CT perfusion, and MR imaging. The current evidence for the use of these newer modalities is described for the diagnosis of SAH.
Comment	Additional information to „Marshall, Nyquist, u. a., 2010“. No access to the full-text article.
Doppler-device	Not known
Quantification	See comment. Concerns only with the diagnosis of SAH.

### Effectiveness of transcranial Doppler ultrasonography for the detection of vasospasm in the anterior cerebral arteries.

Author	(Claudio E Scherle-Matamoros und Pérez-Nellar, 2010)
Content/Summary	The overall precision of the test was good, the specificity and predictive negative value were excellent, but sensitivity was low. The frequency of angiographic vasospasm was 41% in the anterior cerebral arteries (contrast imaging). Sensitivity was 57.9% for flow rates equal to or above 87.5 cm/s, and the predictive positive value was 66.6%.
Comment	56 patients between the 4th and 14th days of their subarachnoid haemorrhage, Article in Spanish
Doppler-device	Not known
Quantification	Low sensitivity. Probably the cut-of-point was too low (87,5 cm/s)?

### Transcranial Doppler for predicting delayed cerebral ischemia after subarachnoid hemorrhage.

Author	(Carrera, Schmidt, Oddo, Fernandez, u. a., 2009)
Content/Summary	Increased TCD flow velocities imply only a mild incremental risk of DCI after SAH, with maximal sensitivity by day 8. Nearly 40% of patients with DCI never attained an mBFV more than 120 cm/s during the course of monitoring. Given the poor overall sensitivity of TCD, improved methods for identifying patients at high risk for DCI after SAH are needed. Furthermore, and perhaps more concerning, was the fact that 16% of patients who did develop DCI never had any mBFV more than 120 cm/s, suggesting that low TCD values might falsely reassure clinicians that the vasospasm risk is low
Comment	Maybe the complexity of vessel identification affects the low sensitivity.
Doppler-device	Pioneer TC 4040; Nicolet Biomedical, Inc., Madison, WI
Quantification	High BFV does not predict DCI

### Accuracy of transcranial Doppler ultrasonography and single-photon emission computed tomography in the diagnosis of angiographically demonstrated cerebral vasospasm.

Author	(Kincaid u. a., 2009)
Content/Summary	Transcranial Doppler ultrasonography appears to be highly predictive of an angiographically demonstrated vasospasm in the MCA and ACA; however, its diagnostic accuracy was lower with regard to vasospasm in the BA. Single-photon emission computed tomography was not predictive of a vasospasm in any of the vascular territories assessed.
Comment	One hundred fifty-two patients (101 women) with a mean age (+/- standard deviation) of 53 +/- 13 years were included.
Doppler-device	Not known
Quantification	Good PPV for vasospasm even in the ACA

### Transcranial Doppler for predicting delayed cerebral ischemia after subarachnoid hemorrhage.

Author	(Carrera, Schmidt, Oddo, Ostapkovich, u. a., 2009)
Content/Summary	Early elevations of mBFV correlate with acute angiographic vasospasm and are associated with a significantly increased risk of DCI. Transcranial Doppler ultrasound may be an early useful tool to identify patients at higher risk to develop DCI after SAH. An elevated admission mBFV >90 cm/s during the first 48 h (adjusted OR = 2.7, p = 0.007) and a poor clinical grade (Hunt-Hess score 4 or 5, OR = 3.2, p = 0.002) were associated with a significant increase in the risk of DCI.
Comment	199 patients who had at least 1 middle cerebral artery (MCA) transcranial Doppler examination within 48 h of SAH onset
Doppler-device	Not known
Quantification	Early high BFV may predict DCI

### Clinical usefulness of transcranial Doppler ultrasound imaging in the diagnosis of cerebral vasospasm in subarachnoid haemorrhage. A validation study.

Author	(C E Scherle-Matamoros u. a., 2008)
Content/Summary	Monitoring with TCD proved to be useful for diagnosing cerebral vasospasm in patients with a good initial clinical status. Most of the patients had mean cerebral blood flow rates of or below 120 cm/s. The peaks of mean blood flow rate were obtained between the fourth and the tenth day. Overall precision, sensitivity and the predictive negative value of TCD were good. Specificity was excellent for flow rates below 130 cm/s, and the predictive positive value was low.
Comment	study included 89 patients with SAH of a non-traumatic origin. Article in Spanish.
Doppler-device	Not known
Quantification	TCD is a useful tool.

### Is Transcranial Doppler Ultrasonography Old-fashioned?: One Institutional Validity Study.

Author	(Han u. a., 2008)
Content/Summary	TCD is still considered a useful tool for screening clinical vasospasm. To confirm the predictive value of the above parameters, further prospective study will be needed. The best TCD parameters for the detection of clinical vasospasm were revealed to be differences of BFVm, BFVh, and LR values between 1(st) TCD test and 3(rd) TCD (7 cm/s, 11.5 cm/s, 0.45 respectively). The positive predictive value of any one of three parameters was 60% and the negative predictive value was 100%.
Comment	study enrolled 40 patients presented with aneurysmal SAH between September 2006 and August 2007. Korean study published in an Korean magazine.
Doppler-device	Not known
Quantification	The change/shift of mBFV seems to be more predictive than absolute mBFV.

### Role of transcranial Doppler in optimizing treatment of cerebral vasospasm in subarachnoid hemorrhage.

Author	(Darwish u. a., 2008)
Content/Summary	On the basis of our results, resistance area product can be used to estimate the optimal arterial blood pressure in hypervolemia/hypertension/hemodilution therapy. Estimated cerebral perfusion pressure from transcranial Doppler data analysis showed poor correlation with cerebral perfusion pressure derived from direct measurement of intracranial pressure in patients with cerebral vasospasm.
Comment	study included 18 adult patients, Hunt and Hess grades III-IV
Doppler-device	Not known
Quantification	TCD results were used to guide the Triple-H therapy. TCD-CPP in vasospasm patients was not correlated to invasive derived CPP.

### Vasospasm after SAH due to aneurysm rupture of the anterior circle of Willis: value of TCD monitoring.

Author	(Fontanella u. a., 2008)
Content/Summary	Our study shows a good correlation between TCD and angiography to detect vasospasm on MCA, but the correlation is low for ACA. TCD alone cannot discriminate different hemodynamic pathways after SAH. TCD vasospasm was observed in 216 patients (27%). In 97% of patients with TCD vasospasm on middle cerebral artery (MCA) and in 71% with TCD vasospasm on anterior cerebral artery (ACA), control angiography confirmed the vasospasm, with a significant lower diagnostic TCD predictivity of ACA spasm (chi2=28.204, p=0.000)
Comment	786 cases admitted within 48 hours after SAH due to the rupture of anterior circulation aneurysm, were prospectively studied with TCD
Doppler-device	Not known
Quantification	Good correlation between TCD and DSA for MCA. Huge patient sample size.

### Transcranial Doppler monitoring in subarachnoid hemorrhage: a critical tool in critical care.

Author	(Rigamonti u. a., 2008)
Content/Summary	Transcranial Doppler ultrasonography assists in the clinical decision-making regarding further diagnostic evaluation and therapeutic interventions. When performed in isolation, the contribution of TCD to improving patient outcome has not been established. Nevertheless, TCD has become a regularly employed tool in neurocritical care and perioperative settings.
Comment	One of the most often cited article in context of TCD, review 1980 to 2007
Doppler-device	Review in context of TCD and TCCD
Quantification	Provides a good overview to TCD in general. This paper has been cited in other publications very often.

### The value of CT angiography and transcranial Doppler sonography in triaging suspected cerebral vasospasm in SAH prior to endovascular therapy.

Author	(Ionita u. a., 2008)
Content/Summary	Clinical evaluation and TCD can reliably diagnose CVS in symptomatic patients and PMV >180 cm/s, or can rule out CVS in asymptomatic patients with PMV <140 cm/s. In this category of patients, adding a CTA to clinical evaluation and TCD may not be warranted.
Comment	55 consecutive patients with aneurysmal SAH who underwent sequential TCD and CTA were analyzed.
Doppler-device	Spencer PMD 100
Quantification	Cut-off point of >180 cm/s reliably diagnosis spasm

**Vasospasm probability index: a combination of transcranial Doppler velocities, cerebral blood flow, and clinical risk factors to predict cerebral vasospasm after aneurysmal subarachnoid hemorrhage.**

Author	(Gonzalez u. a., 2007)
Content/Summary	<p>The selected model for estimation of clinical vasospasm included Fisher grade, Hunt and Hess grade, and spasm index. The VPI had a global accuracy of 92.9% for clinical vasospasm detection.</p> <p>The combination of predictive factors associated with the development of vasospasm in the new index reported here has a significantly superior accuracy compared with the independent tests and may become a valuable tool for the clinician to evaluate the individual probability of cerebral vasospasm after aneurysmal SAH.</p> <p>The selected model for estimation of clinical vasospasm included Fisher grade, Hunt and Hess grade, and spasm index. The VPI had a global accuracy of 92.9% for clinical vasospasm detection. For diagnosis of angiographic vasospasm, the model included Fisher grade, Hunt and Hess grade, and Lindegaard ratio. The VPI achieved a global accuracy of 89.9% for angiographic vasospasm detection.</p>
Comment	Forty-one women (60.3%) and 27 men (39.7%) between the ages of 35 and 84 years (58.0 +/- 13.2 years [mean +/- standard deviation]) were included
Doppler-device	Not known
Quantification	Calculating of this TCD depending index may improve predictive value of TCD measurements.

**Transcranial cerebral oximetry and transcranial Doppler sonography in patients with ruptured cerebral aneurysms and delayed cerebral vasospasm.**

Author	(Constantoyannis u. a., 2007)
Content/Summary	<p>Transcranial cerebral oximetry seems to be of limited value for the detection of vasospasm in patients with subarachnoid hemorrhage. However, it may be useful in estimating the clinical impact of triple-H therapy in such patients.</p> <p>No significant difference (p=0.14) was found in the levels of regional oxygen saturation (rSO<sub>2</sub>) between patients with vasospasm and those without. In patients who developed clinical vasospasm, the blood flow velocity values were significantly higher compared with those who did not (127.5+/-2.7 versus 92.5+/-1.2 cm/sec, p&lt;0.001)</p>
Comment	Pre- and postoperative serial transcranial cerebral oximetry and transcranial Doppler sonography (TCD) examinations were performed in 75 patients
Doppler-device	Multigon 500M
Quantification	NIRS not superior to TCD

### Accuracy of transcranial Doppler sonography for predicting cerebral infarction in aneurysmal subarachnoid haemorrhage.

Author	(J.-Y. Lee u. a., 2006)
Content/Summary	Vasospasm on TCD was found to be predictive of symptomatic cerebral infarction on CT, but its positive predictive value remained low despite the adoption of restrictive TCD criteria for vasospasm.
Comment	93 patients
Doppler-device	Not known
Quantification	

### Transcranial Doppler grading criteria for basilar artery vasospasm.

Author	(Sviri u. a., 2006)
Content/Summary	A BA/VA ratio higher than 3.0 with BA velocities higher than 85 cm/s was associated with 92% sensitivity and 97% specificity for BA narrowing of more than 50%. The BA/VA ratio improves the sensitivity and specificity of TCD detection of BA vasospasm. On the basis of the BA/VA ratio and BA mean velocities, we suggest new TCD grading criteria for BA vasospasm.
Comment	123 patients
Doppler-device	Not known
Quantification	92% sensitivity and 97% specificity for BA narrowing of more than 50%.

### Relative changes in flow velocities in vasospasm after subarachnoid hemorrhage: a transcranial Doppler study.

Author	(Naval u. a., 2005)
Content/Summary	Relative changes in flow velocities in patients with aneurysmal SAH correlated better with clinically significant vasospasm than absolute flow velocity indices. Correction for hyperemia improved predictive value of TCD in vasospasm.
Comment	Charts of 50 patients admitted to Hahnemann University Hospital with aneurysmal SAH were reviewed
Doppler-device	Not known
Quantification	Changes in BFV are more predictive than absolute BFV.

## **Summary:**

TCD is still a widely used method to detect and monitor vasospasm. Its specificity is high but the sensitivity is less accurate. It seems that there have been no further improvements in TCD-techniques despite of some mathematical indices since 2006.

Recently some other non-invasive techniques (e.g. NIRS) are under investigation. Currently there is no common opinion if NIRS is equal or superior to TCD.

Improvements in bedside-techniques are needed to detect spasms more sensitively and more reliably and even in more distal branches.

## **Literature**

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