

Vascular and heart surgery

Background:

The benefit of carotid endarterectomy (CEA) in patients with symptomatic severe carotid stenosis is highly dependent on the perioperative stroke rate. Cerebral monitoring plays an important role in reducing the perioperative stroke rate as it allows detection of the main causes of perioperative stroke, being embolism, intraoperative hypoperfusion and postoperative hyperperfusion syndrome. However, some physicians doubt about the benefit of cerebral monitoring and consider it costly and time consuming.

A major advantage of transcranial ultrasound is its suitability for continuous monitoring. Microembolic signals (MES) are brief, high-intensity transients that occur when particulate microemboli or gaseous microbubbles pass through the ultrasound beam.

Literature:

Comparison between transcranial Doppler and Coulter counter for detection of lipid micro embolization from mediastinal shed blood reinfusion during cardiac surgery.

Author	(Eyjolfsson u. a., 2011)
Content/Summary	Strong correlation was found between embolic loads, as measured by transcranial Doppler and Coulter counter ($r=0.79$, $P<0.005$).
Comment	Thirteen patients undergoing cardiopulmonary bypass surgery were investigated. Each patient's cerebral circulation was monitored with transcranial Doppler during the first two minutes after re-transfusion of shed blood and blood was simultaneously sampled and characterised by a Coulter counter.
Doppler-device	Doppler box, DWL
Quantification	This pilot study shows that non-invasive monitoring by transcranial Doppler could be a potential tool to monitor LME (lipid micro embolization) during cardiopulmonary bypass surgery.

The potential benefits and the role of cerebral monitoring in carotid endarterectomy.

Author	(Pennekamp u. a., 2011)
Content/Summary	Electroencephalography, transcranial Doppler, stump pressure and sensory-evoked potentials, are known and used for years. Near-infrared spectroscopy is a relatively new valuable technique, as it is noninvasive, easy to apply and applicable in all CEA patients, but remains to be validated.
Comment	Review
Doppler-device	none
Quantification	In our opinion, cerebral monitoring in general during CEA is essential because it provides direct information regarding new neurological deficits, which might otherwise be missed.

Cerebral hypoperfusion during pediatric cardiac surgery detected by combined bispectral index monitoring and transcranial Doppler ultrasonography.

Author	(Toyama u. a., 2011)
Content/Summary	Bispectral index monitoring (BIS) measures depth of anesthesia and sedation. The case of a neonatal patient who underwent surgical repair for a double aortic arch is presented. During surgery, BIS decreased to 0, and cerebral blood flow (CBF), as measured by transcranial Doppler ultrasonography, could not be detected immediately after clamping of the arch. BIS returned to baseline, and CBF was detected only after the aortic arch was unclamped. The arch was then carefully reclamped during close BIS and CBF monitoring.
Comment	Case report
Doppler-device	??
Quantification	Loss of cerebral perfusion during surgery measured by TCD.

Interpretation of TCD spectral patterns detected during carotid artery stent interventions.

Author	(Jeong u. a., 2011)
Content/Summary	TCD spectral patterns were classified according to the hemodynamic changes that occurred after different portions of the CAS procedures. The relationships among the spectral patterns and the frequency and location of new DWMRI lesions were analyzed.
Comment	TCD spectral changes were classified into 4 patterns: (1) microemboli signals (53, 100%), (2) right-left collateral signals (31/53, 58%), (3) spectral suppression after balloon inflation (31/44, 70%), and (4) continuous spectral suppression after balloon removal (4/44, 9%).
Doppler-device	??
Quantification	Description of different Doppler signal patterns during carotid surgery. Useful for unexperienced users.

Transcranial Doppler findings during thoracic endovascular aortic repair.

Author	(Bismuth u. a., 2011)
Content/Summary	The highest MES counts were generated by the pigtail catheter placement during the diagnostic phase and by device placement during the treatment phase. Embolic count to right/left sides was equal overall. A significant association was found between the total number of MES and postoperative stroke, transient ischemic attack ($P = .0055$), and death ($P = .0053$).
Comment	TCD was used to monitor 20 patients during TEVAR for the treatment of thoracic aortic aneurysms (TAAs)
Doppler-device	??
Quantification	TCD can detect microemboli and is able to identify the procedural aspects most associated with cerebral microemboli.

Multimodal brain monitoring reduces major neurologic complications in cardiac surgery.

Author	(Zanatta u. a., 2011)
Content/Summary	Patients with brain monitoring had a significantly lower incidence of perioperative major neurologic complications (0%) than those without monitoring (4.06%, $p = 0.01$) and required significantly shorter periods of mechanical ventilation ($p = 0.001$) and intensive care unit stays ($p = 0.01$) than controls. The length of postoperative hospital stays did not differ significantly between the 2 groups ($p = 0.57$).
Comment	A retrospective, observational, controlled study
Doppler-device	none
Quantification	This preliminary study suggests that multimodal brain monitoring can reduce the incidence of neurologic complications as well as hospital costs associated with post-cardiac surgery patient care. Furthermore, intraoperative brain monitoring provides useful information about brain functioning, blood flow velocity, and metabolism, which may guide the anesthesiologist during surgery.

Transcranial Doppler sound detection of cerebral microembolism during transapical aortic valve implantation.

Author	(Drewe u. a., 2011)
Content/Summary	See quantification
Comment	Fifty patients (mean age: 80 ± 5 years; mean EuroSCORE: 36 ± 13 %) underwent transapical aortic valve implantation. Intraoperative transcranial Doppler (TCD) sound examination of both middle cerebral arteries (MCA) was used to identify high-intensity transient signals (HITS) and microembolic signals (MES) during seven phases of the procedure.
Doppler-device	??
Quantification	Cerebral microemboli were detected by intraoperative transcranial Doppler sound examinations in all patients during transapical aortic valve implantation. Most of the signals were detected during balloon valvuloplasty and delivery of the prosthetic valve. Postoperatively, there were no clinical signs of new cerebral embolism.

Intraoperative transcranial Doppler ultrasonography monitoring of cerebral blood flow during coronary artery bypass grafting (CABG).

Author	(Kosir und Tetickovic, 2011)
Content/Summary	Study results clearly demonstrated significant differences in blood flow velocity between off-pump and on-pump procedures ($P=0.0001$). The duration of hypoperfusion was longer in on-pump group, whereas shorter periods of more profound hypoperfusion were observed in off-pump group.
Comment	30 patients aged 39-81 undergoing elective coronary bypass surgery with or without cardiopulmonary bypass. 15 patients undergoing off-pump and on-pump CABG each.
Doppler-device	??
Quantification	Brain monitoring with TCD during CABG proved to be a useful tool to detect cerebral hypotension as it provided unique information on cerebral perfusion. Such monitoring may improve the safety of surgical procedures, allowing for hemodynamic interventions to perform rationally and without interruption of surgical procedure.

Cerebral emboli detected by transcranial Doppler during cardiopulmonary bypass are not correlated with postoperative cognitive deficits.

Author	(Rodriguez u. a., 2010)
Content/Summary	Incidence of POCD (postoperative cognitive dysfunction) was 47.3% and 6.3% at 1 week and 3 months after surgery. There was no association between cardiopulmonary bypass counts of HITS (High-intensity transient signals) and POCD at 1 week (P=0.617) and 3 months (P=0.110). No differences in HITS counts were identified at any of the surgical periods between patients with and without POCD.
Comment	We combined 356 patients undergoing coronary artery bypass graft from 2 clinical trials who had both neuropsychological testing (before, 1 week and 3 months after surgery) and transcranial Doppler during cardiopulmonary bypass.
Doppler-device	??
Quantification	Although cerebral microemboli have been implicated in the pathogenesis of POCD, in this study that included low-risk patients undergoing coronary artery bypass surgery, there was no demonstrable correlation between the counts of HITS and POCD.

Dual antiplatelet therapy prior to carotid endarterectomy reduces post-operative embolisation and thromboembolic events: post-operative transcranial Doppler monitoring is now unnecessary.

Author	(Sharpe u. a., 2010)
Content/Summary	As a consequence of this audit, one dose of 75 mg Clopidogrel will continue to be given pre-operatively (in addition to daily 75 mg Aspirin) and routine post-operative TCD monitoring has now ceased.
Comment	Retrospective audit of prospectively acquired data in 297 patients undergoing CEA between 01.08.2006 and 30.07.2009. All received routine Aspirin (75 mg daily) in addition to a single 75 mg dose of Clopidogrel the night before surgery. All underwent completion angiography and those with a temporal window (n = 270) underwent intra- and post-operative TCD monitoring.
Doppler-device	??
Quantification	No MES following Clopidogrel admission. Post-operative TCD is unnecessary.

Microembolic signals and strategy to prevent gas embolism during extracorporeal membrane oxygenation (ECMO).

Author	(Zanatta u. a., 2010)
Content/Summary	Microembolic signals were detected only in patients with the full extracorporeal blood flow supply due to air embolism.
Comment	Six patients suffering of heart failure, four after cardiac surgery and two after cardiopulmonary resuscitation were treated with ECMO and submitted to transcranial doppler monitoring to accomplish the neurophysiological evaluation for coma.
Doppler-device	DWL
Quantification	The gas microemboli, that enter in the blood circulation and in the extracorporeal circuits are not removed by the membrane oxygenator filter. <i>TCD may be helpful for monitoring during ECMO.</i>

Identifying the high-risk patient with clinically relevant embolisation after carotid endarterectomy.

Author	(Sharpe u. a., 2009)
Content/Summary	TCD directed Dextran has abolished stroke due to POCT. A high-risk cohort of patients requiring Dextran can be identified by measuring the magnitude of embolisation in the first 30 min in Theatre Recovery. The vast majority of patients (85%) require no further monitoring.
Comment	Retrospective audit of prospectively acquired data in 821 patients with an accessible temporal window who had undergone 3h of TCD monitoring after CEA.
Doppler-device	???
Quantification	Immediate TCD monitoring following CAS can guide Dextran therapy to avoid Stroke.

Transcranial Doppler study to assess intracranial arterial communication before aortic arch operation.

Author	(Morita u. a., 2008)
Content/Summary	A preoperative left carotid artery compression test with a measurement of the flow of the LMCA is useful to assess the feasibility of interrupting perfusion to the left carotid artery during aortic arch surgery with bilateral axillary artery perfusion.
Comment	Before surgery, the LMCA flow was detected using transcranial Doppler ultrasonography. During manual compression of the left carotid artery, the flow velocity of the LMCA was measured and expressed as a percent in comparison to the precompression value.
Doppler-device	??
Quantification	Preoperative TCD with compression test is useful to plan treatment options.

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.
Comment	Thirty-three patients with microemboli on TCD (13 symptomatic preoperative, 19 postoperative, one both) were treated with tirofiban between 2002 and 2007. All patients had carotid stenosis greater than 70 per cent. TCD monitoring was used during and after tirofiban therapy.
Doppler-device	PC Dop 842 (SciMed, Bristol, UK)
Quantification	Cerebral microemboli were controlled by tirofiban both before and after CEA. Further study is required to compare the relative efficacy of tirofiban and dextran.

Preoperative transcranial and carotid Doppler study in coronary artery bypass graft patients.

Author	(Farhoudi u. a., 2007)
Content/Summary	There were significant correlations between number of involved cerebral arteries and post CABG CNS complications ($p=0.0001$), including stroke ($p=0.007$), and between diabetes mellitus history with these complications ($p=0.012$).
Comment	201 patients undergoing elective and isolated CABG surgery
Doppler-device	??
Quantification	Our results suggest that ICAD is an independent risk factor for CNS complications after CABG surgery. Hence, we recommend pre-CABG evaluation of the cerebral arteries by TCD, for the risk assessment of CABG surgery.

Timing of clinically significant microembolism after carotid endarterectomy.

Author	(Abbott u. a., 2007)
Content/Summary	<p>Post-operatively detected transcranial Doppler (TCD) embolic signals (ES) are associated with an increased risk of carotid endarterectomy (CEA) stroke/TIA.</p> <p>An ES count >10 per recording was identified as the best overall predictor of ipsilateral stroke/TIA (sensitivity 72%, specificity 89%)</p> <p>3/119 (2.5%) patients with 0-10 ES had ipsilateral carotid events compared to 8/22 (36.4%) patients with 11-115 ES (OR = 22.1, 95% CI 4.5, 138.4, p < 0.0001)</p>
Comment	Sequential patients undergoing CEA (enrolled in a randomised, blinded, placebo-controlled trial of peri-operative dextran therapy) had 30-min TCD monitoring in the first post-operative hour. 30-min monitoring was also performed 2-3, 4-6 and 24-36 h post-operatively.
Doppler-device	EME-Nicolet TC 2020 or the DWL Multi-Dop T
Quantification	<p>Patients with clinically significant post-operative microembolism had an approximately 15 times higher risk of ipsilateral stroke/TIA and most were identified during a 30-min study in the first post-operative hour.</p> <p>TCD postoperatively is an useful tool to detect such patients.</p>

Invos Cerebral Oximeter compared with the transcranial Doppler for monitoring adequacy of cerebral perfusion in patients undergoing carotid endarterectomy.

Author	(Fassiadis u. a., 2006)
Content/Summary	Regional oxygen saturation correlates well with FVm during carotid clamping. However, the inability to obtain reliable TCD FVm readings in 35% of patients is a serious disadvantage for this monitor.
Comment	The percentages fall in TCD mean flow velocity (FVm) and CO regional oxygen saturation (rSO ₂) on the ipsilateral side following clamping were recorded and the correlation coefficient and Spearman's coefficient of rank correlation were calculated.
Doppler-device	??
Quantification	It appears that CO is a satisfactory and possibly superior device for monitoring adequacy of cerebral perfusion and oxygenation during CEA in comparison with the TCD.

Clinical application of transcranial Doppler monitoring for embolic signals.

Author	(Azarpazhooh und Chambers, 2006)
Content/Summary	The present article summarizes the significance of MES in different clinical settings and outlines some of the problems to be resolved so that transcranial ultrasound can be applied in clinical practice.
Comment	Review
Doppler-device	None
Quantification	Probably a very good summary.

The amount of solid cerebral microemboli during carotid stenting does not relate to the frequency of silent ischemic lesions.

Author	(Rosenkranz u. a., 2006)
Content/Summary	In patients with Doppler evidence of solid emboli during CAS, the incidence of new DWI lesions was higher (29%) than in patients without Doppler evidence of solid emboli during the procedure (10%); this difference was not statistically significant ($P = .25$). The number of solid microemboli during CAS in patients with new ipsilateral DWI lesions was not significantly different from that in patients without new ipsilateral DWI lesions.
Comment	We performed multifrequency transcranial Doppler detection of solid microemboli in the ipsilateral middle cerebral artery (MCA) during CAS in 27 consecutive patients with symptomatic high-grade carotid stenoses. No embolus protection was used in any of the cases. DWI before and 24 +/- 2 hours after CAS was used to detect new ischemic lesions.
Doppler-device	EmboDop; DWL, Singen, Germany
Quantification	Solid microembolism is a common event during unprotected CAS; however, the frequency of procedure-related silent cerebral lesions appears to be independent of the number of solid cerebral microemboli during the procedure.

Cerebral blood flow during cardiopulmonary bypass in pediatric cardiac surgery: the role of transcranial Doppler--a systematic review of the literature.

Author	(Polito u. a., 2006)
Content/Summary	The introduction of Doppler technology has allowed an accurate monitorization of cerebral blood flow (CBF) during circulatory arrest and low-flow CPB. TCD has also been utilized in detecting cerebral emboli, improper cannulation or cross clamping of aortic arch vessels. Limitations of TCD routine utilization are represented by the need of a learning curve and some experience by the operators, as well as the need of implementing CBF information with, for example, data on brain tissue oxygen delivery and consumption.
Comment	Review
Doppler-device	none
Quantification	In this light, TCD plays an essential role in multimodal neurological monitorization during CPB (Near Infrared Spectroscopy, TCD, processed electro encephalography) that, according to recent studies, can help to significantly improve neurological outcome after cardiac surgery in neonates and pediatric patients.

Analysis of emboli during carotid stenting with distal protection device.

Author	(Chen u. a., 2006)
Content/Summary	See below
Comment	The newly developed multi-frequency transcranial Doppler (TCD) is able to differentiate gaseous from solid emboli. Our goal was to apply this technology to initially characterize emboli detected during carotid stenting with distal protection.
Doppler-device	Embo Dop, DWL
Quantification	Microembolization frequently occurs during stenting even with deployment of the distal protection device. More solid emboli are seen during manipulations associated with lesion crossing. Although novel TCD methods yield a high frequency of embolic signals, further validation of this technique to determine the true nature, size, and number of emboli is needed.

Novel cerebral physiologic monitoring to guide low-flow cerebral perfusion during neonatal aortic arch reconstruction.

Author	(Andropoulos u. a., 2003)
Content/Summary	Mean arterial pressure had a poor correlation with the required bypass flow rate ($r(2) = 0.006$ by linear regression analysis). Fourteen of 34 patients had a cerebral oxygen saturation of 95% during regional low-flow perfusion, placing them at risk for cerebral hyperperfusion if the cerebral oxygen saturation had been used alone to guide bypass flow. Pressure was detected in the umbilical or femoral artery catheter (mean 12 mm Hg) in all patients during regional low-flow perfusion.
Comment	Data were prospectively collected from 34 patients undergoing neonatal aortic arch reconstruction with regional low-flow perfusion. Cerebral oxygen saturation and blood flow velocity were measured by near-infrared spectroscopy and transcranial Doppler ultrasonography, respectively, throughout cardiopulmonary bypass.
Doppler-device	EME Companion; Nicolet Biomedical Inc
Quantification	Cerebral blood flow velocity, as determined by transcranial Doppler ultrasonography, adds valuable information to cerebral oxygen saturation data in guiding bypass flow during regional low-flow perfusion. Its most important use may be prevention of cerebral hyperperfusion during periods with high near-infrared spectroscopic saturation values.

Summary:

Cerebral monitoring in general during CEA is essential because it provides direct information regarding new neurological deficits, which might otherwise be missed.

A study suggests that multimodal brain monitoring, including TCD, can reduce the incidence of neurologic complications as well as hospital costs associated with post-cardiac surgery patient care and even in pediatric care.

In another study, Patients with clinically significant post-operative microembolism had an approximately 15 times higher risk of ipsilateral stroke/TIA and most were identified during a 30-min study in the first post-operative hour. Immediate postoperative TCD may be a useful tool to detect such patients. Additionally some other surgeons use TCD to direct Tirofiban or Dextran therapy.

A small study suggests, that CO is a satisfactory and possibly superior device for monitoring adequacy of cerebral perfusion and oxygenation during CEA in comparison with the TCD.

Experts:

Andropoulos
Zanatta
Sharpe

Literature

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