Noninvasive estimation of intracranial pressure using TCD

Background:

Transcranial Doppler-derived indices of cerebral autoregulation are related to outcome after head injury. TCD measurements on patients admission (pulsatility index, Mx, Sx, ...) are suggested to have a correlation with raised intracerebral pressure. It is subject to recent research to determine this hypothesis.

Literature:

Usefulness of transcranial Doppler-derived cerebral hemodynamic parameters in the noninvasive assessment of intracranial pressure.

Author	Wakerley BR1, Kusuma Y, Yeo LL, Liang S, Kumar K, Sharma AK, Sharma VK.
Content/Summary Abstract	**BACKGROUND:** Transcranial Doppler (TCD) ultrasonography is a noninvasive bedside tool that can evaluate cerebral blood flow hemodynamics in major intracranial arteries. TCD-derived pulsatility index (PI) is believed to be influenced by intracranial pressure (ICP). **OBJECTIVE:** To correlate TCD-PI with cerebrospinal fluid (CSF) pressure (representing ICP), measured by standard lumbar puncture (LP) manometry. **METHODS:** CSF pressures (CSF-P) were measured in 78 patients by LP manometry. Stable TCD spectra were obtained 5 minutes before LP from either middle cerebral arteries using Spencer's head frame and 2-MHz transducer. PI values were calculated from the TCD spectra by an independent neurosonologist. **RESULTS:** Factors displaying a significant relationship with CSF-P included age ($R = -.426$, $P < .0005$); EDV ($R = -.328$, $P = .002$;) and PI ($R = .650$, $P < .0005$). On analyzing dichotomized data (CSF-P < 20 vs. ≥ 20 cm H2 0) TCD-PI was an independent determinant (OR per .1 increase in PI = 2.437; 95% CI, 1.573-3.777; $P < .0005$). PI ≥ 1.26 could reliably predict CSF-P ≥ 20 cm H2 0 (sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy were 81.1%, 96.3%, 93.8%, 88.1%, and 90.1% respectively).
Comment	TCD-derived PI could be used to identify patients with CSF-P ≥ 20 cm H20 and may play an important role as a monitoring tool.

Doppler-device	Sonara Viasys Inc., USA
Quantification	Pulsatility index is a useful marker of changes in intracranial pressure.

Non-invasive intracranial pressure monitoring with transcranial Doppler in a patient with progressive cerebral venous sinus thrombosis.

Author	Wakerley B[1], Yohana K, Luen Teoh H, Tan CW, Chan BP, Sharma VK.
Content/Summary Abstract	In many intracranial disease states, monitoring of intracranial pressure (ICP) is essential to evaluate response to the therapeutic measures as well as estimation of prognosis. Although, direct estimation of ICP is reliable, it is invasive and not possible in all patients.
Comment	Transcranial Doppler (TCD) ultrasonography is a bedside and noninvasive technique that provides reliable and real-time information about cerebral hemodynamics.
Doppler-device	Not known
Quantification	Authors present a case of extensive and progressive cerebral venous sinus thrombosis in which TCD served as an excellent tool for monitoring ICP and the serial observations correlated closely with clinical status and ophthalmological findings.

Non-invasive methods of estimating intracranial pressure.

Author	(Rosenberg u. a., 2011)
Content/Summary	Several methods have been employed to estimate intracranial pressure, including computed tomography, magnetic resonance imaging, transcranial Doppler sonography, near-infrared spectroscopy, and visual-evoked potentials. In addition, multiple techniques of measuring the optic nerve and the optic nerve sheath diameter have been studied.
Comment	We performed a comprehensive review of the literature to evaluate the different methods of measuring intracranial pressure.
Doppler-device	Not known
Quantification	Latest review! Ultrasound measurements of the optic nerve sheath diameter and Doppler flow are especially promising and may be useful in selected settings.

Pulsatile intracranial pressure and cerebral autoregulation after traumatic brain injury.

Author	(Radolovich u. a., 2011)
Content/Summary	The mean PAx was -0.09 (standard deviation 0.21). This negative value indicates that, on average, an increase in ABP causes a decrease in AMP and vice versa. PAx correlated strong with Mx (R (2) = 0.46, P < 0.0002). PAx also correlated with age (R (2) = 0.18, P < 0.05). PAx was found to have as good predictive outcome value (area under curve 0.71, P < 0.001) as Mx (area under curve 0.69, P < 0.001).
Comment	293 patients were studied.retrospectively analyzed data of patients suffering from TBI with brain monitoring. Transcranial Doppler blood flow velocity, ABP, ICP were recorded digitally. Cerebral perfusion pressure (CPP) and AMP were derived. A new index-pressure-amplitude index (PAx)-was calculated as the Pearson correlation between (averaged over 10 s intervals) ABP and AMP with a 5 min long moving average window.
Doppler-device	PCDop 842 Doppler Ultrasound Unit (Scimed, Bristol, UK) or Neuroguard (Medasonics, Fremona, CA).
Quantification	We demonstrated significant correlation between the known cerebral autoregulation index Mx and PAx. This new index of cerebrovascular pressure reactivity using ICP pulse wave information showed to have a strong association with outcome in TBI patients.

Monitoring cerebral autoregulation after head injury. Which component of transcranial Doppler flow velocity is optimal?

Author	(Budohoski, Reinhard, u. a., 2011)
Content/Summary	Association with outcome was significant for Mx and Sx. For favorable/unfavorable and death/survival outcomes Sx showed the strongest association (F = 20.11; P = 0.00001 and F = 13.10; P = 0.0003, respectively). Similarly, indices derived from ABP demonstrated the highest discriminatory value when systolic FV was used (F = 12.49; P = 0.0005 and F = 5.32; P = 0.02, respectively). Indices derived from diastolic FV demonstrated significant differences (when calculated using CPP) only when comparing between fatal and non-fatal outcome.
Comment	300 head-injured patients with blood pressure (ABP), intracranial pressure (ICP), cerebral perfusion pressure (CPP), and FV recordings were studied.
Doppler-device	Not known
Quantification	Systolic flow indices (Sx and Sxa) demonstrated a stronger association with outcome than the mean flow indices (Mx and Mxa), irrespective of whether CPP or ABP was used for calculation.

Noninvasive detection of elevated intracranial pressure using a portable ultrasound system.

Author	(Prunet u. a., 2011)
Content/Summary	Diagnostic accuracies were good and similar for both methods (TCD area under curve, 0.901; TCCS area under curve 0.870; P = .69). The duration of PI measurement was statistically longer with TCCS than TCD (group 1, P < .01; group 2, P < .01).
Comment	Head-to-head comparison of TCD and TCCS methods using intracranial pressure (ICP) measured continuously via an intraparenchymal catheter as the reference standard in 2 groups of 20 neurocritical care patients each.
Doppler-device	TCD and TCCD
Quantification	This work is a pilot study comparing TCCS and TCD in the detection of elevated ICP. This study suggests that a bedside portable ultrasound system may be useful to determine MCA PI with accuracy similar to that of a dedicated TCD device. But TCD is cheaper!

Transcranial Doppler can predict intracranial hypertension in children with severe traumatic brain injuries.

Author	(Melo u. a., 2011)
Content/Summary	TCD had 94% of sensitivity to identify ICH at admission and a negative predict value of 95% to identify normal ICP at admission. Its sensitivity to predict abnormal cerebral perfusion pressure was 80%.
Comment	Non-invasive TCD and ICP monitoring were performed in 117 severe head-injured children. Mean age was 7.6 ± 4.4 years, with a male prevalence (71%). Median initial Glasgow coma scale was 6.
Doppler-device	Not known
Quantification	The high sensitivity of admission TCD to predict ICH and abnormal CPP after trauma demonstrates that TCD is an excellent first-line examination to determine those children who need urgent aggressive treatment and continuous invasive ICP monitoring.

Transcranial Doppler to screen on admission patients with mild to moderate traumatic brain injury.

Author	(Bouzat u. a., 2011)
Content/Summary	Diastolic cerebral blood flow velocities and pulsatility index measurements were different between patients with SND and patients with no SND. Using receiver-operating characteristic analysis, we found the best threshold limits to be 25 cm/s (sensitivity, 92%; specificity, 76%; area under curve, 0.93) for diastolic cerebral blood flow velocity and 1.25 (sensitivity, 90%; specificity, 91%; area under curve, 0.95) for pulsatility index. According to a recursive-partitioning analysis, TCDB classification and TCD measurements were the most discriminative among variables to detect patients at risk for SND.
Comment	
Doppler-device	Waki 1-TC; Atys Medical, Soucieu en Jarrest, France
Quantification	In patients with no severe brain lesions on CT after mild to moderate traumatic brain injury, TCD on admission, in complement with brain CT scan, could accurately screen patients at risk for SND (secondary neurological deterioration).

Critical thresholds for transcranial Doppler indices of cerebral autoregulation in traumatic brain injury.

Author	(Sorrentino u. a., 2011)
Content/Summary	Mx and Mxa demonstrated that worse autoregulation is associated with poorer outcome and greater mortality ($P = 0.0033$ for Mx and $P = 0.047$ for Mxa). Both indices were more effective for prediction of favorable outcome than mortality. Chi-square for Mx showed a double peak with thresholds at 0.05 and 0.3. Mxa had only one peak at 0.3. Peak chi-square for Mx (11.3) was greater than for Mxa (8.7), indicating that Mx was a better discriminant of outcome than Mxa.
Comment	248 sedated and ventilated patients after head injury
Doppler-device	PCDop 842 Doppler Ultrasound Unit (Scimed, Bristol, UK) or Neuroguard (Medasonics, Fremona, CA).
Quantification	We propose that Mx greater than 0.3 indicates definitely disturbed autoregulation and lower than 0.05 good autoregulation. For values between 0.05 and 0.3 the state of autoregulation is uncertain.

Actual evidence for neuro-monitoring-guided intensive care following severe traumatic brain injury

Author	(Stover, 2011)
Content/Summary	
Comment	Review
Doppler-device	Not known
Quantification	A more individualised and flexible treatment concept depends on extended neuromonitoring. The present review addresses current evidence in favour of extended neuromonitoring used to guide treatment options aimed at improving intensive care treatment of patients with severe TBI.

Transcranial Doppler pulsatility index: not an accurate method to assess intracranial pressure.

Author	(Behrens u. a., 2010)
Content/Summary	The mathematical simulations suggest that variations in vessel compliance, autoregulation, and arterial pressure have a serious effect on the ICP-PI relationship.
Comment	Ten patients underwent a lumbar infusion test, applying 4 to 5 preset ICP levels. The ICP-PI regression equation was based on data from 8 patients.
Doppler-device	TC2-64 transcranial Doppler device (EME, Uberlingen, Germany)
Quantification	The in vivo results show that PI is not a reliable predictor of ICP. Mathematical simulations indicate that this is caused by variations in physiological parameters.

New transcranial Doppler index in infants with hydrocephalus: transsystolic time in clinical practice.

Author	(Leliefeld u. a., 2009)
Content/Summary	The transsystolic time (TST) as measured with TCD increased significantly from 176 to 221 ms ($p<0.005$), whereas the pulsatility index (PI) decreased significantly from 1.3 to 1.0 ($p<0.05$) TST has a strong correlation with the ICP ($p<0.005$)
Comment	Twenty-four infants with hydrocephalus underwent non-invasive ICP measurement, magnetic resonance imaging and TCD before and after cerebrospinal fluid (CSF) diversion.
Doppler-device	Not known
Quantification	Measuring TST with TCD can be helpful in the decision-making process about whether to perform CSF diversion in infants with hydrocephalus. Because TST is related solely to the relative changes in the flow velocity caused by intracranial physical properties, it has a closer relation to ICP than the PI and the RI.

Transcranial Doppler pulsatility index is not a reliable indicator of intracranial pressure in children with severe traumatic brain injury.

Author	(Figaji u. a., 2009)
Content/Summary	The sensitivity and specificity of a PI threshold of 1 for examining the ICP threshold of 20 mm Hg were 25% and 88%, respectively. The relationship between CPP and PI was stronger (P = .001, r = -0.41), but there were too few observations below 50 mm Hg to examine PI at this threshold.
Comment	275 TCD studies prospectively collected hin children with severe TBI undergoing ICP monitoring
Doppler-device	Not known
Quantification	The absolute value of the PI is not a reliable noninvasive indicator of ICP in children with severe TBI. Further study is required to examine the relationship between PI and a CPP threshold of 50 mm Hg.

Transcranial Doppler ultrasound goal-directed therapy for the early management of severe traumatic brain injury.

Author	(Ract u. a., 2007)
Content/Summary	Admission TCD was performed 18+/-11 min (T0) after admission, whereas cerebral invasive monitoring was available 242+/-116 min (T1) after admission. At T0, 11 (46%) patients had abnormal TCD values (group 1) and 13 had normal TCD values (group 2); mean arterial pressure was comparable between groups. All group 1 patients received mannitol and/or norepinephrine. At T1, mean arterial pressure was increased compared to admission in group 1 (105+/-17 mmHg vs. 89+/-15 mmHg, $p<0.05$) and only two patients had still an abnormal TCD. Although group 1 patients had higher intracranial pressure than those of group 2 (32+/-13 mmHg vs. 22+/-10 mmHg, $p<0.01$), both cerebral perfusion pressure and jugular venous oxygen saturation were comparable between the groups.
Comment	Twenty-four severely brain-injured patients.
Doppler-device	Not known
Quantification	The use of TCD at hospital admission allows identification of severely brain-injured patients with brain hypoperfusion. In such high-risk patients, early TCD goal-directed therapy can restore normal cerebral perfusion and might then potentially help in reducing the extent of secondary brain injury.

Transcranial Doppler ultrasonography as an early outcome forecaster following severe brain injury.

Author	(Splavski u. a., 2006)
Content/Summary	
Comment	Thirty patients who sustained severe brain injury underwent an early blood velocity measuring by transcranial Doppler ultrasonography during a 1-year period of study.
Doppler-device	Not known
Quantification	Transcranial Doppler ultrasonography for measuring the middle cerebral artery blood flow velocity has been proved worthy as a possible predictor of severe head injury management outcome. This non-invasive and simple procedure could be engaged in the daily management of severely brain-injured patients.

Early transcranial Doppler after subarachnoid hemorrhage: clinical and radiological correlations.

Author	(Miranda u. a., 2006)
Content/Summary	Lower velocities and higher PIs correlated with a worse clinical condition at admission.
Comment	52 consecutive patients diagnosed with SAH, with an abnormal computed tomography (CT) scan on admission and a TCD performed in the first 24 hours from the onset of the hemorrhage, were retrospectively reviewed.
Doppler-device	Not known
Quantification	These findings support the hypothesis that low cerebral perfusion caused by high intracranial pressure leads to diffuse ischemic changes in the early phase of SAH.

Cerebral hemodynamic changes gauged by transcranial Doppler ultrasonography in patients with posttraumatic brain swelling treated by surgical decompression.

Author	(Bor-Seng-Shu u. a., 2006)
Content/Summary	Decompressive craniectomy results in a significant elevation of cerebral BFV in most patients with traumatic brain swelling and transtentorial herniation syndrome. The increase in cerebral BFV may also occur in the side opposite the decompressed hemisphere; the cerebral BFV increase is significantly greater in the operated hemisphere than contralaterally. Concomitantly, PI values decrease significantly postoperatively, mainly in the decompressed cerebral hemisphere, indicating reduction in cerebrovascular resistance.
Comment	Nineteen patients presenting with traumatic brain swelling and cerebral herniation syndrome who had undergone decompressive craniectomy with dural expansion were studied prospectively.
Doppler-device	Not known
Quantification	See content

Summary:

There has been lot of research on this subject during the last years, especially in 2011.
Out of the non-invasive techniques, especially ultrasound measurements of the optic nerve sheath diameter and Doppler flow are promising to estimate intracranial pressure and may be useful in selected settings.

Pulsatility index alone does not seem to be a reliable predictor for intracranial pressure, but there is evidence that Mxa index (derived from BFV and non-invasive measured ABP) and the transsystolic time (TST) do. Furthermore some indices are supposed to be correlated with outcome after traumatic brain injury.

TCD is available immediately after admission and can be performed quickly. Early TCD goal-directed therapy may restore normal cerebral perfusion and might then potentially help in reducing the extent of secondary brain injury, even in children.

Experts:

No one in particular

Literature

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