Validation of Noninvasive Absolute Intracranial Pressure Measurements in Traumatic Brain Injury and Intracranial Hemorrhage

**BACKGROUND:** Increased intracranial pressure (ICP) causes secondary damage in traumatic brain injury (TBI), and intracranial hemorrhage (ICH). Current methods of ICP monitoring require surgery and carry risks of complications.

**OBJECTIVE:** To validate a new instrument for noninvasive ICP measurement by comparing values obtained from noninvasive measurements to those from commercial implantable devices through this pilot study.

**METHODS:** The ophthalmic artery (OA) served as a natural ICP sensor. ICP measurements obtained using noninvasive, self-calibrating device utilizing Doppler ultrasound to evaluate OA flow were compared to standard implantable ICP measurement probes.

**RESULTS:** A total of 78 simultaneous, paired, invasive, and noninvasive ICP measurements were obtained in 11 ICP patient over a 17-mo period with the diagnosis of TBI, SAH, or ICH. A total of 24 paired data points were initially excluded because of questions about data independence. Analysis of variance was performed first on the 54 remaining data points and then on the entire set of 78 data points. There was no difference between the 2 groups nor was there any correlation between type of sensor and the patient (F[10, 43] = 1.516, P = .167), or the accuracy and precision of noninvasive ICP measurements (F[1, 43] = 0.511, P = .479). Accuracy was [−1.130; 0.539] mm Hg (CL = 95%). Patient-specific calibration was not needed. Standard deviation (precision) was [1.632; 2.396] mm Hg (CL = 95%). No adverse events were encountered.

**CONCLUSION:** This pilot study revealed no significant differences between invasive and noninvasive ICP measurements (P < .05), suggesting that noninvasive ICP measurements obtained by this method are comparable and reliable.

**KEYWORDS:** ICP, Noninvasive, Traumatic brain injury, Intracranial hemorrhage

Increased intracranial pressure (ICP) is an important mechanism of secondary brain injury after traumatic brain injury (TBI), intracranial hemorrhage (ICH), and subarachnoid hemorrhage (SAH). ICP rises acutely, and often peaks again later in these conditions. The detrimental role of increased ICP has been well documented. Indeed, the duration and pattern of ICP elevations correlate with functional outcome.

Optimal medical and surgical management of elevated ICP correlates with improved survival. As a result, ICP monitoring and management have been incorporated into several published clinical guidelines. Two techniques are commonly deployed for ICP measurement: intraventricular catheters with manometry, and precalibrated intraparenchymal probes with direct readout. Intraventricular catheters are simple, relatively

**ABBREVIATIONS:** ANOVA, analysis of variance; CL, confidence level; CSF, cerebrospinal fluid; EOA, extracranial segment of the ophthalmic artery; EVD, external ventricular drainage; ICH, intracranial hemorrhage; ICP, intracranial pressure; IOA, intracranial segment of the ophthalmic artery; OA, ophthalmic artery; OC, optic canal; ON, optic nerve; ONSD, optic nerve sheath diameter; PI, pulsatility index; SAH, subarachnoid hemorrhage; TBI, traumatic brain injury; TCD, transcranial Doppler; TMD, tympanic membrane displacement.
### TABLE 1. Inclusion and Exclusion Criteria.

<table>
<thead>
<tr>
<th>Inclusion criteria:</th>
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<tbody>
<tr>
<td>• Adult patients, age ≥ 18 yr, admitted after TBI or SAH at the Department of Neurosurgery, Kantonsspital Aarau, Switzerland</td>
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<tr>
<td>• Patients under sedation and ICP monitoring</td>
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<td>• Informed consent will be obtained from the relatives prior to initiation of the measurements</td>
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<table>
<thead>
<tr>
<th>Exclusion criteria:</th>
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<tr>
<td>• Age &lt; 18 yr at study entry</td>
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<tr>
<td>• Patients with wounds, scars including the front orbital region</td>
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<tr>
<td>• Perforating or penetrating mechanism of TBI</td>
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<tr>
<td>• Patients with orbital injury or abnormal blood flow in both Ophthalmic Arteries</td>
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<tr>
<td>• Patients with previous retina surgery</td>
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<tr>
<td>• Patients with previous cataract surgery</td>
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<tr>
<td>• Patients with any known ocular condition that may be worsened by sustained eye pressure in the opinion of the subject's ophthalmologist</td>
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<tr>
<td>• Patients with radiological signs of calcification or atheromatous plaques in the internal carotid artery detected by CT or angiography (performed prior and independently of the study)</td>
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inexpensive devices that provide for both ICP measurement and drainage of cerebrospinal fluid (CSF). Their limitations include contraindication in the presence of coagulopathy, and impairment of function in the presence of both highly compressed (“slit”), and anatomically distorted ventricles resulting from severe brain swelling or similar causes.11

Both approaches to ICP monitoring require a surgical procedure, and entail an increased risk.12 Infections and intracranial bleeding related to invasive ICP measurement techniques have been described.13–16

Several technologies for noninvasive ICP measurement have been reported. These techniques include transcranial Doppler (TCD) ultrasonography,17 tympanic membrane displacement,18 optic nerve sheath diameter (ONSD),19 and more recently, devices that generate an acoustic signal that propagates through the cranium.20

The objective of this pilot study was to validate a self-calibrating device and method for ICP measurement by simultaneous comparison with standard intraventricular or intraparenchymal methods in TBI and ICH.

### METHODS

#### Background, Objectives, and Trial Design

This investigation was designed as a pilot study to validate a self-calibrating device and method for ICP measurement in TBI and ICH by simultaneous comparison of noninvasive measurements with those obtained via standard intraventricular or intraparenchymal methods. The device to be tested, the Vitramed™ 205 (Vitramed Corporation, Lexington, Massachusetts), has been subjected to extensive safety testing, and is CE marked.21 This study was funded by the Swiss Agency for Development and Cooperation (SDC) and the Swiss National Science Foundation (SNF) as part of a Swiss–Lithuanian collaborative project. Ethics committee approval and Swissmedic approval were obtained. Measurements were obtained at the intensive care unit.

Written, voluntary, and fully informed consent was obtained in all cases, including consent to publish images of the patients.

Inclusion and exclusion criteria are shown in Table 1. All measurements were performed in our intensive care unit on intubated and sedated patients in whom invasive ICP monitoring using intraparenchymal or intraventricular probes were indicated on standard clinical grounds.

A previous study on TBI patients had demonstrated the feasibility of measuring ICP noninvasively without individual patient calibration using the first-generation prototype device.22 The value of that study was limited; however, by the lack of comparison to accepted “gold-standard” invasive ICP measurements.

The current study was designed to compare the accuracy and precision of noninvasive and invasive measurements simultaneously. The study was planned around 20 subjects and 60 independent paired noninvasive and invasive ICP measurements. Several measurements were planned on each patient. We use the term “absolute ICP” to indicate that there is no call for patient-specific calibration in this method, nor is there need for reference to an outside fiducial.

The instrument investigated in this trial was initially developed at the Telematic Science Laboratory at the Kaunas University of Technology, Lithuania.23

#### Technical Background

The measurement technique is based on the use of the ophthalmic artery (OA) as a natural ICP sensor. The OA has 2 major segments. The first, the proximal or intracranial segment, originates at the carotid artery and extends to the optic canal (OC), at which point it perforates the dura. The second, the distal or intraorbital segment of the OA originates distal to the OC and accompanies the optic nerve (ON) within the orbit to the retina.

Proximal but not distal to the OC, the OA is subject to ICP, resulting in a difference between transmural pressures in the proximal and distal OA, demonstrable by Doppler ultrasound. Absent other pertinent influences, these differences are attributable to the influence of ICP.

The orbital contents are noncompressible. Pressure applied to the orbit is transferred, therefore, to the distal, intraorbital OA. This phenomenon allows transmural pressures of the proximal and distal OA to be balanced. The pressure required is equal to the ICP. The ICP can be read off the instrument when the balance point is reached. This is the principle by which noninvasive ICP values are obtained with this instrument.
Pulse dynamics and flow velocity are assessed by means of a customized transorbital Doppler ultrasound device equipped with a 2-depth single beam transducer. The examination is unilateral. Either side can be used. Contraindications include vascular or other anatomic anomalies, difficulty in measurement, orbital injury, or a history of certain categories of orbital or ocular surgery or disease. Disqualification on one side does not contraindicate the use of the other.

In use, the transducer is inserted into a holder on a plastic frame strapped around the head (Figure 1). It is fitted through a disposable doughnut-shaped inflatable cushion about 7.5 cm in diameter situated between the frame and the orbit (see Video, Supplemental Digital Content 1, which illustrates the setup of simultaneous measurement of invasive and noninvasive ICP in the ICU). The cushion applies controlled stepwise pressure.

Next, the ultrasound is used to scan the orbit and confirm the position and course of the OA. The transducer is adjusted for optimal signal strength and quality. The width of the ultrasound beam is engineered to insonate both segments of the OA simultaneously.

As already noted, the transducer passes through the opening in the cushion. It is positioned against the closed eyelid and fixed in place after proper alignment. Pressure in the cushion is monitored continuously throughout the measurement procedure. The ICP measurement is automated from the point at which the position of the ultrasonic transducer has been fixed.

Pressure is increased in 2- or 4-mm increments until the balance point is reached. The smaller increment improves precision at the expense of examination time (Figure 2). Setup time ranges between 15 and 20 min. In experienced hands, examination time ranges from 10 to 20 min. The learning curve is variable.

Validation Criteria and Statistical Analysis

The hypothesis tested was that noninvasive ICP measurement using the Vittamed 205 device (Vittamed Corporation) noninvasively would not differ significantly from those obtained using invasive intraparenchymal or intraventricular techniques. Microsensor intraventricular probes (Silverline 8FS, Spiegelberg, Germany) were utilized for comparison in 9 patients, and intraparenchymal probes (3PS, Spiegelberg, Germany) in 2. Noninvasive measurement yields a single value. The invasive ICP values used for comparison were derived by averaging the continuous values obtained over the time frame of the invasive measurement.

Differences between noninvasive and invasive measurements were displayed on a Bland–Altman plot. Acceptable accuracy for noninvasive measurement was defined as ±4.0 mm Hg and displayed as ±4.0 mm Hg error corridor on the Bland–Altman plot with a confidence level (CL) ≥ 95%. The value of ±4.0 mm Hg was predicated on the size of the incremental pressure steps. The corridor could be decreased to ±2 mm Hg by using 2-mm pressure steps.

Both sets of ICP readings were corrected for height differences between the proximal OA and the ventricular catheter or intraparenchymal probe based on CT measurement. Corrections were reflected in the Bland and Altman data plots.

Statistical Methods

Invasive and noninvasive measurements were compared accounting for the potential confounding influences of the different sensors used and the number of patients monitored (within and between factors). An unbalanced mixed-model ANOVA (analysis of variance) was applied. The type of sensor was considered as a fixed effect with 2 levels; each subject was considered as a random effect with 11 levels. The level of significance was set at $P = .05$. Statistical analysis was performed using IBM SPSS Statistics software (version 23.0; IBM Corporation, Armonk, New York).

Data sphericity was not assumed: The Greenhouse–Geisser correction was used.

Because the number of patients was small, data point independence was also examined. The criteria initially established for data inclusion to assure independence therefore were (1) removal and repositioning of the headframe between measurements and (2) a change ≥4 mm Hg or greater successive measurements in the same patient. We expected to find extensive variability in ICP values. Surprisingly, we did not. In this cohort only 54/78 measurements (70%) varied by ≥4 mm Hg; 24/78 (30%) did not.

As a result, we performed 2 ANOVA analyses. The first included the 54 paired data points that met inclusion criteria, while the second included all 78 paired data points. Results were substantially the same.

Adverse Events

During the 18-mo study period no adverse event related to the device or setup for the measurement was recorded. So far, no episodes of arterial hypotension due to orbital pressure during the measurements were observed.

RESULTS

Patient Demographics

A total of 29 patients were screened for the study (Figure 3). Eleven patients were excluded due to orbital or eyelid trauma, headframe size mismatch, and unrelated death or systemic complications during ICU treatment prior to measurement. Eighteen patients were included in the “intent to test” group.
Seven were excluded because of technical, operator, or subject-specific limitations (Table 2), leaving 11, 5 females and 6 males, to be studied. Mean age was 52 yr (±8.3). Three patients had TBI, 5 SAH, and 3 ICH (Table 3).

Measurements

As noted, 78 paired data points were collected and analyzed: 54 met strict independent inclusion criteria, while 24 did not. Nevertheless, each of the 24 seemed as though it might be independent after all because the headframe was removed and replaced because ICP measurements from the implanted continuous measuring device had clearly varied by more than the stipulated amount even if the Vittamed 205 (Vittamed Corporation) did not.

For this reason, an ANOVA was performed first on each of the 54 paired independent data points meeting strict inclusion criteria and then upon the entire group of 78 paired data points. Finally, the 2 sets of paired data points were compared.

In the set of 54 paired independent data points, the differences between invasive and noninvasive measurements met the normal distribution law ($P = .320$). The observed covariance matrices of the dependent variables were equal (Box’s M = 17.45, $P = .543$), thus meeting the assumption of homogeneity of intercorrelations. So was Levine’s test of equality of error variances: the error variance of the dependent variable was equal across groups. An unbalanced mixed ANOVA was therefore used.

There was no significant correlation between sensor type, subject ($F[10, 43] = 1.516, P = .167$), and accuracy or precision of noninvasive ICP measurement ($F[1, 43] = 0.511, P = .479$) in this group. Accuracy was $[-1.130; 0.539]$ mm Hg (CL = 95%). Precision was $[1.632; 2.396]$ mm Hg (CL = 95%).

In the set of 78 measurements, calculated accuracy of the noninvasive measurements was 0.10 mm Hg and the calculated precision was 1.88 mm Hg.
Because there was no significant difference in the results of the ANOVA between the 2 groups, we chose to show graphically the analysis of the set of 78 data points in the Bland–Altman plot in Figure 4. Linear regression plot is shown in Figure 5.

In 11 out of 78 measurements (not related to inclusion criteria), a warning code relating either to temporarily low Doppler signal, to readings from the invasive devices, or to extra systoles was displayed. A separate Bland–Altman calculation was carried out for these 11 cases. Mean accuracy of the noninvasive measurements was 0.04 mm Hg with a precision of 1.97 mm Hg. This did not differ significantly from the group in the aggregate (accuracy of 0.10 and standard deviation of 1.88 mm Hg). Nevertheless, a post hoc review of these data was undertaken to look for unexplained causes of error. None was found. The data were deemed, therefore, to be valid, and included.

**DISCUSSION**

Noninvasive ICP measurement based on 2-depth TCD is safe, reliable, accurate, and precise. The technique is based on well-accepted techniques. There is no statistically significant difference...
### Table 2. Reasons of Measurements’ Failures.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Reason for exclusion of measurement</th>
<th>Clinical</th>
<th>Patient</th>
<th>Operator</th>
<th>Technical</th>
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<tr>
<td>1</td>
<td>Measurement not reliable IOA strong clutter</td>
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<td>x</td>
<td>x</td>
<td></td>
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<tr>
<td>2</td>
<td>Extrasystolic heart beats</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>3</td>
<td>Measurement not reliable, low signal</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Measurement not reliable, low signal</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Measurement not reliable, Pe(t) range incorrect</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Extrasystolic heart beats</td>
<td>x</td>
<td>x</td>
<td>x</td>
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</tr>
<tr>
<td>7</td>
<td>Malfunction of the invasive ICP probe with fluctuations</td>
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<td>x</td>
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### Table 3. Demographic Characteristics.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Age</th>
<th>Disease</th>
<th>ICP invasive</th>
<th>ICP noninvasive</th>
<th>Type of ICP probe</th>
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<tr>
<td>1</td>
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<tr>
<td>2</td>
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<td>SHT</td>
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<tr>
<td>3</td>
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<td>SAH</td>
<td>7.3</td>
<td>6.94</td>
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<tr>
<td>4</td>
<td>Male</td>
<td>55</td>
<td>ICH</td>
<td>11.6</td>
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<tr>
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<td>Male</td>
<td>49</td>
<td>ICH</td>
<td>7.7</td>
<td>7.2</td>
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<tr>
<td>6</td>
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<td>58</td>
<td>ICH</td>
<td>12.93</td>
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<tr>
<td>7</td>
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<td>40</td>
<td>SHT</td>
<td>24.8</td>
<td>25.5</td>
<td>EVD</td>
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<tr>
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<td>41</td>
<td>SHT</td>
<td>13.5</td>
<td>13.37</td>
<td>EVD</td>
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<tr>
<td>9</td>
<td>Female</td>
<td>69</td>
<td>SAH</td>
<td>14.5</td>
<td>12.97</td>
<td>EVD</td>
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<tr>
<td>10</td>
<td>Male</td>
<td>37</td>
<td>SAH</td>
<td>9</td>
<td>8.53</td>
<td>EVD</td>
</tr>
<tr>
<td>11</td>
<td>Female</td>
<td>65</td>
<td>SAH</td>
<td>6.17</td>
<td>6.83</td>
<td>EVD</td>
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</table>

between mean invasively measured ICP values and noninvasive values obtained by this method.

The most common findings associated with acutely decreased level of consciousness in patients with TBI and SAH are intracranial or intracerebral lesions such as bleeding, concussion, contusion, epidural and subdural hematoma, and depressed skull fractures.  

Several alternative techniques for noninvasive ICP measurement have been developed and remain in desultory use. These include algorithms based upon CT and dynamic MRI sectional imaging, 25-27 simultaneous TCD sonography of the MCA and arterial blood pressure monitoring, 28-30 near-infrared spectroscopy, 31 visual evoked potentials, 32 tympanic membrane displacement (TMD), 33 pulsatility of the ocular circulation, 34 measurement of ONSD, 35 ophthalmodynamometry, 36 quantitative pupillometry, 37,38 and orthoacoustic emission. 39,40 Ganslandt et al 20 recently reported on promising results in a validation study comparing invasive ICP measurement with a noninvasive device using advanced signal analysis algorithms that evaluate an acoustic signal emitted from the ipsilateral ear.

Techniques based on sectional imaging based on MRI use the correlation between pressure and intracranial compliance to estimate ICP. 41 Alperin et al 30 demonstrated a correlation between MR imaging derived elastance index (Δ pressure/Δ volume) and invasive measured ICP. Marshall et al 42 however, examined the variability of these parameters and concluded that reliability and repeatability were poor to modest. From a practical perspective, moreover, MRI examination is time consuming and expensive.

It has also been suggested that the shape of the basilar cisterns as shown on sectional imaging could be correlated with increased ICP. 43 Using a model involving 5 measurable parameters, ventricle size, basilar cistern size, sulci size, degree of trans-falcine herniation, and gray/white matter differentiation, Miller et al 44 furthermore concluded that a linear relationship between CT characteristics and ICP could be demonstrated. No predictive model, however, was ever achieved. Indeed, using this approach to dimension reduction, one is forced to conclude that a normal CT scan cannot actually exclude the presence of elevated ICP. That limitation, if no other factor, limits the utility of this approach. 45,46

The Gosling pulsatility index (PI) has been correlated with ICP in conjunction with TCD to compare peak systolic and end-diastolic flow velocities. 47-52 PI has also been correlated with cerebral perfusion pressure and pCO₂ levels. 49,53 Reliability of measurement has not been adequate and application has been limited. 50,54,55
FIGURE 4. Bland–Altman plot of paired data points of simultaneous data points derived from noninvasive absolute ICP (aICP) value measurements and invasive aICP measurements: 11 included TBI/SAH/ICH patients, 78 paired data points (invasive aICP is measured using Codman microsensors: blue points – 76 paired data points with intraventricular ICP probe, red points – 2 paired data points with intraparenchymal ICP probe). Here: Δ – absolute difference (absolute error) of paired noninvasive and invasive aICP data; Mean aICP is a mean value of invasively and noninvasively measured aICP values; green lines – absolute error Δ corridor (± 4.0 mm Hg) caused by externally applied pressure's Pe(t) sampling step, which is equal to 4.0 mm Hg; vertical red lines – two clinically important aICP thresholds: neurological patients' general critical aICP threshold 14.7 mm Hg and severe TBI/SAH/ICH patients’ critical aICP threshold 20.0 mm Hg.

FIGURE 5. Regression line plot with ideal range of aICP from 0 mm Hg up to 50 mm Hg. Comparison of the noninvasive aICP method in the ICU for patients with TBI/SAH using 76 intraventricular invasive and 2 subdural invasive aICP measurement points as a reference. The graph shows the absolute corridor ± 4.0 mm Hg, red line – the critical aICP threshold that is 20.0 mm Hg.
TMD measurement is based on the relationship between CSF and cochlear fluid pressure. The TMD technique measures the response to the elicitation of the acoustic reflex. A significant correlation with invasively measured ICP in patients with hydrocephalus has been elicited, but the predictive limits are too wide for clinically useful ICP measurement. Another problem is the absence of a stapedial reflex in relaxed and sedated patients or the presence of brainstem and middle ear dysfunction.

Ultrasonographic measurement of ONSD is predicated on the expansion of the optic sheath with increased ICP. Correlation coefficients ranging from 0.46 to 0.74 have been reported. This technique is limited by a 2.2- to 4.9-mm age-dependent variation in ONSD, and limitation on use with ocular trauma or pathology of the ON.

None of these noninvasive techniques has entered broad clinical use. Problems have included workflow issues, accuracy and statistical significance, and a need for patient-specific calibration. The use of the OA as an ICP sensor, in contrast, does not suffer these limitations.

A recent prospective clinical study comparing this method to lumbar puncture yielded a systematic error less than 1.0 mm Hg and an SD ± 2.3 mm Hg. Results from this trial yielded a CL of 98.71% for the confidence interval within ± 4.0 mm Hg, confirming a previous study using lumbar puncture for comparison, and matching, thereby, the standards for invasive ICP measurements. This level of accuracy and precision meets clinical requirements and confirms that patient-specific calibration is unnecessary.

Our experience with the technology and instrumentation reported here suggests that it is more time consuming than the surgical implantation of ICP probes at this stage of development. Nevertheless, we believe that the introduction of this technique will have the potential to reduce the prevalence of surgical complications and might assist in predicting the risks of intraventricular catheter insertion.

Further studies around noninvasive ICP measurement in other neurological disorders, such as brain tumors with mass effect, stroke, and glaucoma, are ongoing.

**Limitations**

Adequate training and skill are required. The instrument should be operated by an experienced orbital or TCD ultrasound technician. At this stage of development, the measurement process may require 15 min or more. Quicker measuring times are preferable. It is necessary to stock a range of headframe sizes to obtain a good fit. Four sizes suffice for adults, but the size range for infants and children has yet to be delineated.

Should ICP become highly unstable, the point of equilibrium may be difficult to pinpoint.

No adverse events associated with the Vittamed 205 device (Vittamed Corporation) interfered with the performance or completion of the study. Although unrelated extra cardiac systoles
were judged initially to interfere with measurement in 2 patients, measurements were later performed successfully. No significant cardiac events or arrhythmias were recorded.

In theory, stiffening of the OA may interfere with measurements in older populations. This possibility will be assessed systematically in a planned upcoming study that will include stroke patients.

Pressure on the orbit is contraindicated in some patients with previous ocular surgery. The contralateral orbit, however, is not necessarily excluded. No adverse ophthalmic events have been reported, moreover, in over 300 patients tested by ophthalmologists at the Lithuanian University of Health Sciences (Kaunas, Lithuania) using the same technology to study normal and high-tension glaucoma.67

Further development of software and hardware components of this device are being pursued to improve usability, optimize signal quality, simplify measurement, and reduce the time for measurement. It is likely that many of the limitations noted may be mitigated in the next generation of the device.

CONCLUSION

This pilot study validated a method and an instrument for noninvasive ICP measurement. It was not intended as a large-scale study comparing the Vittamed (Vittamed Corporation) approach for noninvasive ICP monitoring to invasive ICP measurements more broadly. Nevertheless, the data demonstrated negligible differences between the invasively and noninvasively measured mean ICP values ($P < .05$). Patient-specific calibration was not needed and there were no adverse events. On this basis, we conclude that noninvasive ICP measurement based on 2-depth TCD techniques is safe, reliable, accurate, and precise. Additional, larger scale clinical studies will be pursued.

Disclosures

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REFERENCES


34. Querfurth HW, Lagreze WD, Hedges TR, Heggerick PA. Flow velocity |V O L U M E 0|N U M B E R 0|2 0 1 8


COMMENT

The authors report on the accuracy and reliability of a non-invasive means of measuring intracranial pressure. In this method, ICP is estimated by applying pressure to the orbit to equilibrate transmural pressure differences induced by intracranial pressure on the proximal ophthalmic artery. The authors demonstrate a high level of accuracy as well as the ability to follow intracranial pressures serially without patient-specific calibration. Much like the recent deployment of portable CT scanners and transcranial Doppler units with first responders, one can envision the need for such a device for rapid assessment of intracranial
pressure in the trauma setting or other acute care settings. These data points can be critical and we should be striving to put them in the hands of health care providers, especially when accurate and reliable. Shortcomings of the current study are the lack of assessment of ICPs outside the “normal” range and the current practical limitations related to the size of the assessment tool. Technology always gets smaller and further studies are planned, so these obstacles should be overcome. Ultimately, we may envision a hybrid non-invasive sensor based on multiple biosignals to improve the care of neurosurgical patients.

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