Optic Nerve Sheath Ultrasound for the Bedside Diagnosis of Intracranial Hypertension: Pitfalls and Potential

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Abstract

Raised intracranial pressure is a complication not just of traumatic brain injury and other acute cerebral insults, but also of a number of general medical conditions. Bedside diagnosis can be difficult; early clinical signs may be misinterpreted, and reliance on cross-sectional imaging studies may further delay diagnosis. Ultrasound is a readily available imaging modality in most critical care areas, and examination of the optic nerve sheath by bedside ultrasound allows detection of changes in diameter which may indicate intracranial hypertension. This paper reviews optic nerve sheath anatomy as a basis for its potential to provide a window on changes within the intracranial cerebrospinal fluid (CSF) space, the technique of sonographic measurement of optic nerve sheath diameter (ONSD), the evidence for correlation with intracranial pressure, and the comparison of ONSD with the ‘gold standard’ method of intracranial pressure assessment.

Keywords: Intracranial hypertension; Bedside ultrasound; Optic nerve sheath diameter; Ocular ultrasound

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Introduction

Bedside ultrasound scanning, particularly echocardiography and thoracoabdominal sonography, is widely used in the intensive care unit and emergency department to exclude life-threatening pathology. The use of ultrasound of the optic nerve and its sheath to diagnose time-critical raised intracranial pressure following traumatic brain injury is less widely practiced, but has been described in several small studies over the past two decades.

The diameter of the optic nerve sheath has been found to be a strong predictor of raised intracranial pressure, with a high sensitivity and specificity in multiple studies and in a systematic review [1]. Raised intracranial pressure is a common emergency following brain injury, with prompt diagnosis having a significant impact on morbidity and mortality [2].

Ultrasound measurement of the optic nerve sheath diameter (ONSD) allows repeated noninvasive assessments of intracranial pressure and facilitates evaluation of the response to treatment. As invasive intracranial pressure monitoring is typically restricted to neurosurgical centres, this mode of investigation is particularly suited to patients suspected of raised intracranial pressure prior to transfer for definitive treatment, as well as patients who continue to be cared for in non-neurosurgical critical care units. In addition to its diagnostic goal, there is some, albeit limited, evidence to suggest that ONSD can also be used for prognostication [3, 4].

The majority of articles on ONSD measurement are in the setting of raised intracranial pressure secondary to traumatic brain injury. However, a few studies have used this measurement to diagnose or assess the severity of other pathologies, including meningitis, stroke, hepatic encephalopathy, epilepsy, and acute mountain sickness [5–9].

The potential value of this technique is reflected in the significant number of studies performed to date. Unfortunately, most have small patient numbers and hence low power, and could be criticised for potential observer bias. Efforts are ongoing to define the ONSD indicating ‘true’ raised intracranial pressure, the best sonographic approach to visualise the optic nerve sheath, the optimum axis to assess the optic nerve sheath, and the impact of operator experience on measurement variability.
While papilloedema may take time to develop, dilation of the optic nerve sheath, optic nerve sheath diameter, optic ultrasound, optic nerve sonography, and optic nerve ultrasonography. These terms were searched for separately and in combination with the terms intracranial pressure and papilloedema. Further studies were identified by examining the reference lists of included articles. This yielded a total of over 100 articles. After review, forty-two articles were judged to be directly relevant to the topic discussed and are referenced.

The anatomy of the optic nerve sheath

The intraorbital section of the optic nerve extends from the globe, where it inserts medially, to the optic canal located in the lesser wing of the sphenoid bone. It is encased by a meningeal sheath consisting of dura mater, arachnoid mater and pia mater. Cerebrospinal fluid is contained in the trabeculated subarachnoid space and is continuously and slowly filtered. As a result the optic nerve sheath is in direct communication with the intracranial subarachnoid space. It is this relationship that forms the physiological basis for using the optic nerve sheath as a surrogate for intracranial pressure measurement.

The anatomical relationships underpinning the use of ultrasound to measure ONSD can be readily appreciated on MRI (Figure 1).

![Figure 1. MRI anatomy of the optic nerve and sheath](image)

Case courtesy of Dr Frank Gaillard, Radiopaedia.org. From the case Optic nerve and chiasm (MRI anatomy)

The optic nerve sheath is bound more loosely to the optic nerve closer to the globe. This loose binding creates a much larger, and potentially more distensible, subarachnoid space in this region, which can appear bulbous on ultrasound [10]. While papilloedema may take time to develop, dilation of the optic nerve sheath occurs much earlier and may be a near-instantaneous manifestation of raised intracranial pressure [11, 12].

The history of imaging the optic nerve

The first report of ultrasound imaging of the eye was in 1956, but it was early cadaver studies which implicated the optic nerve sheath in the measurement of intracranial pressure. One such study noted the “bulbous portion of the optic nerve was seen to bulge or inflate somewhat as the intracranial pressure was created” with the infusion of crystalloid into the brain [13]. The authors also noted this appeared to occur anteriorly, where the nerve sheath was at its thinnest and most expandable. These early studies did not measure the ONSD, relying on imprecise visual clues, and were hampered by the limited ultrasound modes available. These early modes made it difficult to locate a distinct point for measurement at a reproducible distance behind the globe.

As ultrasound modalities improved, the focus of most studies was the optimum distance behind the globe at which to best measure ONSD. A 1996 study using modern ultrasonographic techniques showed that ONSD increased by up to 60% at a distance of 3 mm behind the globe in comparison to only 35% at 10 mm [12]. This has been confirmed in subsequent studies, indicating that a position 3 mm behind the globe is preferred for measurement [14]. Measurements made at this point are more reproducible since ultrasound contrast is greater at this depth with a linear probe. Consistent with this, the optic nerve sheath is at its most distensible anteriorly, where it is potentially most reflective of raised intracranial pressure.

The sonographic appearance of the optic nerve sheath

On ultrasound, the globe is visualised as a round, dark, fluid filled structure (see Figure 2). The anterior chamber is anechoic, as generally is the lens, while the iris appears bright and echogenic. The choroid and retina may be seen as a thin grey layer at the posterior aspect of the globe. The optic nerve is the ‘black stripe’ running away from the posterior aspect of the globe and optic disc, and should ideally be positioned in the centre of the ultrasound screen. The nerve sheath, as seen on ultrasound examination, has a high reflectivity compared to the homogenous appearance of the nerve, and should be relatively easy to distinguish.

If the optic nerve sheath is markedly dilated, it may be possible to diagnose this from visual estimation alone. In general, however, the software calipers should be used to ensure accurate measurement and recording. In severely raised intracranial pressure, it may be possible to visualise a ‘crescent sign’ [15], an echoluent circular artefact within the sheath separating the sheath from the nerve due to increased subarachnoid fluid.

There has been interest in using contrast enhanced ultrasound (CEUS) to help identify and recognise the anatomy surrounding the optic nerve, which is a small structure. The incorrect identification of artefacts as part of the sheath by an inexperienced sonographer is a criticism of the technique. A small proof of concept study, using a second generation contrast agent (Sonovue®, Bracco SpA), found good correlation between CEUS and MRI. This study suggests, by using non-toxic contrast, exact measurements can be more quickly and easily delineated, which may lessen the effect of operator inexperience [16].

Pros and cons of measurement of ONSD by ultrasound

Sonographic ONSD assessment brings some clinical advantages but also some downsides that need to be considered when adopting the technique.
Advantages include:

- reproducibility of measurements
- the non-invasive nature of the technique
- ready availability of equipment
- portability of equipment
- rapid performance
- relatively low costs
- avoidance of ionising radiation
- avoidance of patient transport for imaging

The primary clinical disadvantage, given the relative novelty of the technique, lies in the ongoing lack of a uniform cut-off value for the diagnosis of raised intracranial pressure (see below). Practical disadvantages are manageable and relate primarily to the need to acquire competence in the scanning technique to optimise accuracy, the potential risk of pressure injury to the globe if technique is poor, and the potential for injury resulting from thermal and non-thermal effects of ultrasound.

Ultrasound is generally acknowledged to be a safe technique [17]. The largely hypothetical risks of ultrasound centre on the potential biological consequences of interaction between the scanned tissues and the ultrasound wave. These consequences may be thermal or non-thermal, and are measured by the safety indices Thermal Index (TI) and Mechanical Index (MI), which are displayed in real-time on the screen of most modern ultrasound machines. Ultrasound is presumed to be safe when the values of the TI and MI are less than 1.0 [18]. The TI is the ratio of the power used to the power required to produce a temperature rise of 1°C [18].

Ultrasound energy from the probe passes into scanned tissues and is reflected from tissue interfaces; some energy is absorbed and converted to thermal energy, elevating the temperature of local tissues. Scanning time should be minimised to prevent possible thermal injury. It is advised that tissue temperature increase should be kept below 1.5 °C.

The MI gives an approximate figure of the risk of the non-thermal effects. These include cavitation, which is the expansion and contraction of tissue gas bubbles during the cycle, and streaming, referring to the movement of complex fluids brought about by the ultrasound energy. The MI gives an approximate figure of the risk of the non-thermal effects.

Optic nerve sheath ultrasound should not be used in the presence of evident or suspected rupture of the globe, or when there is significant periorbital injury. The technique is likely to be of limited incremental value in patients with chronically raised intracranial pressure or long-standing papilloedema.

The technique of optic nerve sheath ultrasound

Although individual clinicians may vary in certain aspects of their examination technique, there are some general principles which will help optimise ocular ultrasound for assessment of the ONSD:

- Select the high frequency linear array probe on the ultrasound machine as this provides the best compromise between footprint and resolution of superficial structures.
- Apply ultrasound gel liberally to the closed eyelid. If desired, a clear thin dressing (e.g. IV cannula dressing) can be used as a barrier between the closed eyelid and the gel medium although this is not strictly necessary.
- Resting the probe hand on a bony structure such as the forehead or brow ridge stabilises the image and lowers the risk of inadvertent pressure on the globe.
- Place the ultrasound probe lightly over the gel in a transverse orientation initially. There should neither be any direct contact of the probe with the eyelid nor pressure exerted on the globe. The probe marker should be orientated laterally (Figure 3a).
- With small, subtle movements scan from side to side (i.e. temporal to nasal), slowly angling the probe superiorly or inferiorly to bring the optic nerve into view. The nerve will appear as a ‘black stripe’ running posteriorly from the rear of the globe. The goal is to centre this on the monitor. If the lens or iris is not seen in your image, the imaging plane is likely off-axis and may result in an underestimation of ONSD.
- The globe should also be scanned in the parasagittal plane, with the probe marker superiorly, towards the patient’s forehead (Figure 3b).
- Both eyes should be scanned, in case of unilateral papilloedema.
- The time spent in active scanning should be minimised. Once the optimum view has been obtained, store the image either as a frame or a video loop and remove the probe from the eye. Measurements can then be performed without unnecessary exposure of the eye to ultrasound energy.
- Use the caliper function on the ultrasound to enable precise measurement. First locate a point 3 mm posterior to the optic disk. At this point place the calipers at 90 degrees to the axis of the optic nerve to measure the diameter of optic nerve and optic nerve sheath (Figure 4).
• Take the average of two or three measurements for each side.

A 1996 study by Helmke & Hansen suggested the optimal scanning orientation was longitudinal (axial), as this was associated with the least inter-observer variability [12]. However, aside from the variability findings, there was no significant difference in measurements between the two orientations.

Most patients will be scanned supine, or with a 20° to 30° head up tilt. A Nepalese study, which included 287 patients, examined the correlation between ONSD and acute mountain sickness. This study suggested ONSD does not change with patient positioning [9]. This was supported by results from a healthy adult study by Romagnuolo [19]. In that study three investigators measured the ONSD in 10 separate volunteers and concluded the diameter measured by ultrasound does not change significantly with either standard Trendelenburg or reverse Trendelenburg, in comparison with a baseline supine position. The data on the impact of body position on ONSD should not be extrapolated beyond the clinical settings which have been studied, and more work remains to be done.

Differential diagnosis

Although uncommon in critical care practice, there are alternative causes for a rise in ONSD and these should be kept in mind when diagnosing raised intracranial pressure in a patient with increased ONSD. The differential diagnosis of increased ONSD includes:

- raised intracranial pressure
- optic neuritis
- arachnoid cyst of the optic nerve
- anterior orbital masses
- cavernous sinus masses
- trauma to the optic nerve
- optic nerve sheath meningioma

Establishing the ONSD cut-off for diagnosis of raised intracranial pressure

Evidence from multiple studies supports correlation between ONSD and opening pressure of cerebrospinal fluid or intracranial pressure in both adults and children [2, 14, 20–22]. Table 1 summarises the main clinical studies reporting an association between ONSD and intracranial pressure. Some studies show a high sensitivity and negative predictive value for the detection of further increases in intracranial pressure [2, 23]. A more recent study attempted to investigate the impact of brainstem death on ONSD, as compared to patients in a state of coma [24]. In this study, ONSD was measured in 29 brainstem dead patients, 19 comatose patients (11 with indications of raised intracranial pressure), 20 patients with established neurological disease and 40 healthy subjects as controls. While the comatose and brainstem dead patients showed a markedly increased ONSD in comparison to the other two groups, there was limited evidence to suggest brainstem death could be reliably distinguished from coma on the basis of ONSD.

On review of earlier studies, a tentative association emerged between an ONSD of 5.0 mm and the presence of raised intracranial pressure. In a study of 59 emergency department patients, Tayal [2] found an ONSD of 5.0 mm had a 100% sensitivity to detect patients with raised intracranial pressure. Another emergency department study by Qayyum, found a sensitivity and specificity of 100% and 75%, respectively, for a cutoff of 5.0 mm, with positive and negative predictive values of 94.5 and 100% [23].

However, there remains controversy about the exact diameter of the optic nerve sheath that best predicts elevated intracranial pressure. The bulk of studies recruited less than 100 patients and indicate a 5 mm cut-off. However, other studies have found evidence for different optimal cut-offs. Rajajee and colleagues used 5.2 mm as their upper limit of normal measurement [25]. Soldatos used 5.7 mm [26], and Bäuerle used 5.8 mm [20]. The variation in cut-off across studies is significant, and ranges from 4.8 mm to 6.0 mm [25, 27–29]. This makes it more difficult to establish a ‘set’ measurement above which raised intracranial pressure can be diagnosed based on ONSD.

There are multiple explanations for the differences in the upper limit of normal. The studies from 1996-2015 focused on...
heterogeneous patient populations. The majority of studies were done on ICU and emergency department patients and compared a control group with a group that might reasonably be expected to have a high intracranial pressure. Not all studies attempted to stratify results by gender or ventilatory status, both factors which may affect results. A significant proportion were performed in medical inpatients requiring a lumbar puncture for neurological disease, or in outpatients undergoing treatment for intracranial hypertension. While it was standard in most studies (where stated) to use a 7.5 MHz linear ultrasound probe, this was not always the case. Lastly, the 'confirmation' of raised intracranial pressure was done with a variety of different methods – MRI, CT, invasive intracranial pressure monitors, and CSF opening pressure. This makes comparison between studies difficult.

Of note, ethnic differences may need to be taken into account when measuring ONSD as a surrogate measure of ICP. A study in Chinese patients correlated an elevated opening pressure on lumbar puncture with a significantly lower ONSD than in Caucasian populations [30].

ONSD measurement has not been widely examined in paediatric patients and no strong evidence to diagnose raised intracranial pressure exists. One study, in 64 paediatric patients, reported a very low specificity of ONSD for raised intracranial pressure [31].

Also, a small porcine study noted a lack of correlation between ONSD changes and central venous pressure. It is possible ONSD alone is a poor indicator of change in intracranial pressure when the rise in intracranial pressure is solely influenced by a rise in central venous pressure [32].

**Comparison of ONSD by ultrasound with other methods of assessing intracranial pressure**

Studies of sonographic ONSD have mainly correlated findings with clinical and radiological signs and symptoms of elevated intracranial pressure. Intraventricular measurement is the gold standard for measuring intracranial pressure. These measurement devices carry many risks, including haemorrhage and infection. These complications partly account for increasing interest in non invasive methods such as neuroimaging, transcranial Doppler sonography, ONSD ultrasonography and CT/MRI. In addition, invasive methods may not be available to individual patients due to contraindications, such as coagulopathy, thrombocytopenia, or the lack of local facilities.

The correlation of ONSD with intraventricular pressure monitoring has not been widely examined, probably because of the invasive nature of the latter and the limited pool of patients available. Kimberly correlated ventriculostomy intracranial pressure measurements with ONSD [21]. They found a positive correlation with a Spearman rank correlation coefficient of ONSD and ICP of 0.59 ($p < 0.0005$). Similarly, the area under the ROC curve for ability of ONSD to distinguish an ICP greater than 20 cm H$_2$O was 0.93. Their results indicated a reasonably high specificity of 93% and sensitivity of 88%.

This compares well with the data from clinical and radiological studies. For example, Blaivas correlated ONSD
<table>
<thead>
<tr>
<th>Author (ref)</th>
<th>Patients (n)</th>
<th>Comparison groups (mean/range ONSD)</th>
<th>Optimal cut-off (sensitivity/specificity)</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hansen and Helmke 1997 [11]</td>
<td>39</td>
<td>Control range 2.7 - 4 mm Patients with raised ICP 3.6 - 6.8 mm</td>
<td>5 mm</td>
<td>ICU, children 7.5 MHz probe</td>
</tr>
<tr>
<td>Blaivas et al 2003 [33]</td>
<td>35</td>
<td>Patients without raised ICP, mean 4.42 mm Patients with raised ICP, mean 6.27 mm</td>
<td>5.0 mm Sensitivity 100%, specificity 95%</td>
<td>ED, adults 10 MHz probe</td>
</tr>
<tr>
<td>Geeraerts et al 2007 [27]</td>
<td>31</td>
<td>Patients without raised ICP, up to 5.1 mm Patients with raised ICP, up to 6.3 mm</td>
<td>5.7 mm Sensitivity 100%</td>
<td>ICU, adults 7.5 MHz probe</td>
</tr>
<tr>
<td>Tayal et al 2007 [2]</td>
<td>59</td>
<td>Patients with raised ICP, &gt;5mm</td>
<td>5 mm Sensitivity 100%, specificity 63%</td>
<td>ED, adults 7.5 MHz probe</td>
</tr>
<tr>
<td>Kimberly et al 2008 [21]</td>
<td>15</td>
<td>Patients without raised ICP, mean 4.4 mm Patients with raised ICP, mean 5.4 mm</td>
<td>5 mm Sensitivity 88%, specificity 93%</td>
<td>ED/ICU adults 10 MHz probe</td>
</tr>
<tr>
<td>Soldatos et al 2008 [26]</td>
<td>76</td>
<td>Control without raised ICP, mean 3.6 mm Patients with raised ICP, mean 6.1 mm</td>
<td>5.7 mm Sensitivity 74%, specificity 100%</td>
<td>ICU, adults</td>
</tr>
<tr>
<td>Geeraerts et al 2008 [28]</td>
<td>37</td>
<td>Head injury patients requiring ICP monitor</td>
<td>5.9 mm, AUC ROC 0.91 Sensitivity 90%, specificity 84%</td>
<td>ICU, adults 7.5 MHz probe</td>
</tr>
<tr>
<td>Goel et al 2008 [34]</td>
<td>100</td>
<td>Patients without raised ICP, mean 3.5 mm Patients with raised ICP, mean 5.8 mm</td>
<td>5 mm Sensitivity 98.6%, specificity 92.8%</td>
<td>Trauma, adults 7.5 MHz probe</td>
</tr>
<tr>
<td>Watanabe 2008 [35]</td>
<td>12</td>
<td>Pre-v-post-op chronic subdural collections Mean 6.1 mm pre-op, 4.8 mm post-op</td>
<td>No cut-off given</td>
<td>Neurosurgery MRI used</td>
</tr>
<tr>
<td>Moretti et al 2009 [36]</td>
<td>53</td>
<td>Controls, mean 4.9 mm Patients without raised ICP, mean 5 mm Patients with raised ICP, mean 6.2 mm</td>
<td>5.2 mm Sensitivity 93%, specificity 74%</td>
<td>ICU, adults 7.5 MHz probe</td>
</tr>
<tr>
<td>Moretti et al 2009 [22]</td>
<td>63</td>
<td>Patients without raised ICP, mean 5 mm Patients with raised ICP, mean 6.4 mm</td>
<td>5.2 mm Sensitivity 94%, specificity 76%</td>
<td>ICU, adults 7.5 MHz probe</td>
</tr>
<tr>
<td>Bauerle et al 2011 [20]</td>
<td>10</td>
<td>Controls, mean 5.4 mm Patients with raised ICP, mean 6.4 mm</td>
<td>5.8 mm Sensitivity 90%, specificity 84%</td>
<td>Non-ICU neuro Adults</td>
</tr>
<tr>
<td>Rajajee et al 2011 [25]</td>
<td>65</td>
<td>Patients without raised ICP, mean 4 mm Patients with raised ICP 5.3 mm</td>
<td>4.8 mm Sensitivity 96%, specificity 94%</td>
<td>ICU, adults</td>
</tr>
<tr>
<td>Strumwasser et al 2011 [29]</td>
<td>10</td>
<td>Trauma patients requiring ICP monitoring</td>
<td>6 mm Sensitivity 26%, specificity 38%</td>
<td>ICU, adults</td>
</tr>
<tr>
<td>Cammarata et al 2011 [37]</td>
<td>21</td>
<td>Controls, mean 5.51 mm Patients without raised ICP, mean 5.52 mm Patients with raised ICP, mean 7 mm</td>
<td>No cut-off stated r=0.74 for correlation of ONSD with ICP</td>
<td>ICU, adults</td>
</tr>
<tr>
<td>Amini et al 2013 [38]</td>
<td>50</td>
<td>Patients without raised ICP, mean 4.6 mm Patients with raised ICP, mean 6.7 mm</td>
<td>5.5 mm Sensitivity 100%, specificity 100%</td>
<td>Neuro, adults</td>
</tr>
<tr>
<td>Qayyum et al 2013 [23]</td>
<td>24</td>
<td>Patients with suspected raised ICP Compared against CT findings</td>
<td>5 mm Sensitivity 100%, specificity 75% Positive predictive value 95.4%</td>
<td>ED, adults</td>
</tr>
<tr>
<td>Caffery et al 2014 [39]</td>
<td>51</td>
<td>ONSD against opening pressure on LP with 20 cmH₂O chosen</td>
<td>5 mm pre-selected cut-off Sensitivity 75%, specificity 44% AUC on ROC 0.69</td>
<td>ED, adults Non-trauma</td>
</tr>
<tr>
<td>Shirodkar 2014 [6]</td>
<td>101</td>
<td>Control, male 4.8 mm, female 4.6 mm Patient with raised ICP, mean 5.4 mm</td>
<td>4.6 mm for females: sensitivity 84.6%, specificity 100% 4.8 mm for males: sensitivity 75%, specificity 100%</td>
<td>Medical, adults</td>
</tr>
<tr>
<td>Mehrpour 2015 [40]</td>
<td>32</td>
<td>Patients with raised ICP, mean 6.24 mm</td>
<td>5.7 mm Sensitivity 100%</td>
<td>Neuro, adults 7.5 MHz probe</td>
</tr>
<tr>
<td>Wang et al 2015 [30]</td>
<td>279</td>
<td>No high opening pressure 3.55 mm With high opening pressure 4.58 mm</td>
<td>4.1 mm Sensitivity 95%, specificity 92% AUC ROC curve 0.965</td>
<td>Neuro, Chinese adults 9-3 probe</td>
</tr>
<tr>
<td>Topcuoglu et al 2015 [24]</td>
<td>29</td>
<td>Controls, mean 4.69 mm Neurological disease, mean 4.36 mm Coma raised ICP, mean 5.89 mm Coma no raised ICP, mean 5.16 mm Brainstem dead, mean 6.09 mm</td>
<td>No cut-off (attempt to identify ONSD difference between brainstem dead and coma with raised ICP)</td>
<td>ICU, adults</td>
</tr>
</tbody>
</table>

Table 1. Summary of clinical studies investigating ONSD.
with radiological signs of raised intracranial pressure, as defined by the presence of mass effect with midline shift greater or equal to 3 mm, a collapsed third ventricle, hydrocephalus or the effacement of sulci with evidence of significant oedema, and found a sensitivity of 100% and specificity of 95% for ONSD compared to CT, with positive and negative predictive values of 93% and 100% respectively [33]. With regard to neuroimaging, Soldatos found good correlation of ONSD with CT findings in brain-injured adults (r = 0.68, P = 0.002) [26]. MRI is often spoken of as a reference test for ONSD, as it has higher spatial resolution, and the images offer a more representative calculation of the mean diameter, than CT. While Lagrèze and colleagues contend the accuracy of MRI exceeds sonographic methods for determining ONSD [41]. Bauerle showed good scan-rescan reproducibility and good observer agreement in 15 healthy volunteers [20].

Transcranial doppler (TCD) has also been investigated, but sonography windows were often inadequate. While some studies have generally found it to be a poor predictor of intracranial pressure, others have found the method based on two depth TCD more reliable than ONSD measurement [42–44]. This last study enrolled 92 patients and compared both non-invasive methods of measurement with CSF pressure obtained by lumbar puncture, using a cut-off for ICP of 14.7 mmHg and 5 mm for ONSD. The sensitivity and specificity of TCD were better than ONSD (sensitivity 37% for ONSD, 68% for TCD, specificity 58.5% for ONSD, 84.3% for TCD). The area under the ROC curve was 0.57 for ONSD and 0.87 for TCD. Skill acquisition, acoustic window availability, and ease of use may favour ultrasound assessment of ONSD by critical care clinicians over TCD, in spite of potential diagnostic advantages of TCD.

ONSD in practice

From the available evidence, it is reasonable to conclude that optic nerve ultrasound has utility as part of the non-invasive assessment of intracranial pressure, and may offer potential means of reducing complications associated with intraventricular intracranial pressure monitors by better targeting those devices. Naturally, the technique will not be viable in some patients, such as those with severe ocular trauma, and it must be borne in mind that a number of aetiologies other than raised intracranial pressure can lead to dilatation of the optic nerve sheath.

Increased ONSD may also be of prognostic significance. Legrand found that ONSD, as measured on brain CT in 77 patients, was independently associated with ICU mortality, albeit at greater than 7 mm [4].

It may be argued the main value of this technique lies in early evaluation, during the initial assessment and resuscitation or transport phases, where cross-sectional imaging is unavailable. Similarly, the technique may be of value in bedside assessment in the ICU, although studies are needed to determine if this is a viable strategy to reduce the need for CT or MRI imaging.

For medical patients at risk of raised intracranial pressure, such as those with liver failure, this straightforward bedside assessment may be helpful in risk stratification and decision-making around the timing of, and need for, CT imaging. This assessment would also be beneficial in these patients prior to procedures such as central line insertion, as part of the decision-making process around target vein and patient position during access.

Conclusion

The studies to date have generally been small and poorly powered with the inevitable result that many questions remain unanswered. There is a clear opportunity for the critical care community to collaborate on larger scale studies to evaluate the potential impact of pathways using ultrasound assessment of ONSD.

ONSD values greater than 5 mm, and certainly greater than 5.8 mm, have been shown to be highly specific and sensitive for the presence of raised intracranial pressure. Elevated ICP should be considered in the presence of an ONSD greater than 5mm, and if greater than 5.5 mm urgent consideration should be given to medical management pending further diagnostic workup. In adolescents and non-Caucasian populations, the thresholds are likely to vary and additional data is required before recommendations can be made.

It is important that physicians using this technique are proficient in clinical ultrasound to minimise errors and adverse effects due to poor scanning technique. Fortunately ONSD measurement by ultrasound is readily taught. For governance, training, and quality monitoring purposes the indication for performance of ONSD assessment should be recorded along with the technique and findings. These should be reviewed in light of results of additional investigations such as CT or MRI.

References


