American Journal of Emergency Medicine 35 (2017) 150–153

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/ajem

Diagnostics

Optic nerve sheath diameter measurement: a means of detecting raised ICP in adult traumatic and non-traumatic neurosurgical patients

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ARTICLE INFO

Article history:
Received 27 July 2016
Received in revised form 18 September 2016
Accepted 20 September 2016

ABSTRACT

Introduction: Bedside ultrasound measurement of optic nerve sheath diameter (ONSD) is emerging as a non-invasive technique to evaluate and predict raised intracranial pressure (ICP). It has been shown in previous literature that ONSD measurement has good correlation with surrogate findings of raised ICP such as clinical and radiological findings suggestive of raised ICP.
Objectives: The objective of the study is to find a correlation between sonographic measurements of ONSD value with ICP value measured via the gold standard invasive intracranial ICP catheter, and to find the cut-off value of ONSD measurement in predicting raised ICP, along with its sensitivity and specificity value.
Methods: A prospective observational study was performed using convenience sample of 41 adult neurosurgical patients treated in neurosurgical intensive care unit with invasive intracranial pressure monitoring placed in-situ as part of their clinical care. Portable SonoSite ultrasound machine with 7 MHz linear probe were used to measure optic nerve sheath diameter using the standard technique. Simultaneous ICP readings were obtained directly from the invasive monitoring.
Results: Seventy-five measurements were performed on 41 patients. The non-parametric Spearman correlation test revealed a significant correlation at the 0.01 level between the ICP and ONSD value, with correlation coefficient of 0.820. The receiver operating characteristic curve generated an area under the curve with the value of 0.964, and with standard error of 0.22. From the receiver operating characteristic curve, we found that the ONSD value of 5.205 mm is 95.8% sensitive and 80.4% specific in detecting raised ICP.
Conclusions: ONSD value of 5.205 is sensitive and specific in detecting raised ICP. Bedside ultrasound measurement of ONSD is readily learned, and is reproducible and reliable in predicting raised ICP. This non-invasive technique can be a useful adjunct to the current invasive intracranial catheter monitoring, and has wide potential clinical applications in district hospitals, emergency departments and intensive care units.

1. Introduction

The diagnosis of elevated or raised intracranial pressure (ICP) is both challenging and critical. This is because early detection and subsequent prompt treatment of this elevated ICP can prevent secondary brain damage, which is the leading cause of death in neurosurgical patient especially in severe traumatic brain injury [1-3,13].

The current gold standard measurement of detecting raised intracranial pressure is through an invasive procedure by placement of intracranial catheter into the ventricles or the cerebral parenchyma. Intracranial pressure can be definitively measured and monitored through devices such as intraparenchymal catheter or an external ventricular drain (EVD) catheter [15].

Bedside sonographic measurement of optic nerve sheath diameter is emerging as a noninvasive technique to detect elevated ICP. Increased ICP is transmitted to the subarachnoid space surrounding the optic nerve, causing optic nerve sheath expansion, and the expansion of this cerebrospinal fluid (CSF) space can easily be detected using ultrasound. Various methods of measuring the optic nerve sheath diameter (ONSD) has been studied previously; in postmortem specimens (direct measurement) [9], children with ventriculoperitoneal shunts (ultrasound measurement) [8], and emergency department patients with head injuries [4-7,11].

The aim of the study is to find a correlation between sonographic measurements of ONSD value with ICP value measured via the gold standard invasive intracranial ICP catheter, the cut-off value of ONSD

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http://dx.doi.org/10.1016/j.ajem.2016.09.044
0735-6757/

measurement in predicting raised ICP, and to compare these values in traumatic and non-traumatic patients.

2. Methods

2.1. Study design

This is a prospective observational study of adult neurosurgical patients treated in neurosurgical intensive care unit with invasive intracranial pressure monitoring placed as part of their clinical care. The sampling method is non-probability sampling. The patients are enrolled as a convenience sample based on the availability of the primary investigator. The study participant would include any patient admitted to neurosurgical intensive care unit requiring sedation and invasive ICP monitoring for various reasons.

2.2. Subject criteria

The patient included in the study were divided into two arms; patients with traumatic brain injury and patients without traumatic brain injury. Example of patient with traumatic brain injury that may be included are patients with severe head injury requiring cerebral protection and ICP monitoring, which can be pre or post craniotomy. Examples of patient without head injury that could be included into the second arms are patients with post aneurysm clipping with EVD in-situ, patients with spontaneous intracerebral bleed or intraventricular bleed with EVD in-situ, intraventricular tumor or any other brain tumor with hydrocephalus and EVD in-situ. Another group of patients with presumed normal ICP were recruited as the control group. These are the patients without any ICP catheter and with clinical and radiological evidence of normal ICP.

2.3. Research tools

Ocular ultrasound measurement of the optic nerve sheath diameter was done using the SonoSite (SonoSite Inc., Bothel) machine with 7.5 MHz linear probe, using the standard technique. ICP catheter such as Spiegelberg intraparenchymal catheter or EVD catheter would have already been placed as part of the patient's clinical management. The ICP value detected by these catheters were readily displayed on the monitor and was documented simultaneously with the ultrasound measurement of the optic nerve sheath diameter.

The ultrasonographic methods for measuring the optic nerve sheath diameter is the standard technique described in literature. Patient is examined in the supine position. Conductive gel is placed over a closed eyelid. The linear ultrasound probe from the portable ultrasound machine is simply placed over the closed eyelid to obtain axial cross-sectional image of the optic nerve. CSF surrounding the optic nerve sheath receives direct pressure transmission from cerebral CSF, and the maximal diameter fluctuations is noted as bulging of the dura mater 3 mm behind the papilla, of which the measurements will be taken. Three measurements will be taken from each eye and the average value of the 6 measurements or the mean ONSD is documented. Simultaneous reading of the ICP value for this patient is also documented after each ONSD measurement. The resulting 6 ICP value is also averaged to yield the mean ICP. This documented mean ONSD and the mean ICP is the value taken for further statistical analysis.

The ultrasound measurements were done together with a neuroradiologist for the first 20% of the sample size as a validation test. Our calculated sample size was 30 patients; therefore, the ONSD measurements of 6 patients in the initial phase of the study were performed together with a neuroradiologist. The neuroradiologist then verified and certified that her measurements are comparable to the measurements taken by the primary investigator, with inter-observer variations of +/−0.1 mm. The subsequent measurements were then taken by the primary investigator.

2.4. Statistical analysis

The data collected will first be plotted against a scatter plot to look for positive correlation. A non-parametric Spearman's correlation test is chosen to further analyze the data. The significance level is set at .05. Subsequently receiver operating characteristic (ROC) curve was performed to determine optimal ONSD cutoff point to detect high ICP when high ICP is defined as more than 20 mmHg.

3. Results

A total of 41 patients were recruited in this study. They were divided into two arms; Traumatic Group and Non-Traumatic Group. This division was based on the working diagnosis on admission. From the total 41 patients, 21 patients (51.22%) were in the Traumatic Group and 20 patients (48.78%) were in the Non-Traumatic Group. The patients were aged 19 to 66 with mean age of 33.48 years old. Twenty-eight patients (68.29%) were male and 13 patients (31.71%) were female.

Seventy-five ocular measurements were performed on 41 patients. Of those, 39 measurements (52%) were taken from patients in the Traumatic Group, and 36 measurements (48%) were from the Non-Traumatic Group.

A total of 75 measurements were taken from only 41 patients, which means some patients had multiple measurements taken while some only a single reading. This occurs when there are changes in the ICP value, either elevated or decreased. As pointed on the table above, of the 41 patients, 20 patients (48.78%) had a single ONSD measurement each, 9 patients (21.95%) had 2 measurements, 11 patients (26.83%) had 3 measurements, and 1 patient (2.44%) had 4 measurements.

Thirty patients with presumed normal ICP were included in the control group arm. The mean optic nerve sheath diameter for the control group in our study is 4.57 mm. The patients in this control group were neurosurgical patients without invasive ICP catheter in-situ and with presumed normal ICP based clinical and radiological findings that were suggestive of normal ICP.

The non-parametric Spearman's correlation test revealed a significant correlation at the .01 level between the ICP and ONSD value, with correlation coefficient of 0.820. The ROC curve generated an area under the curve with the value of 0.964, and with standard error of 0.22. At 95% confidence interval, the lower boundary for this area under the curve is 0.921 and the upper boundary is 1.000 (see Figs. 1 and 2). From the

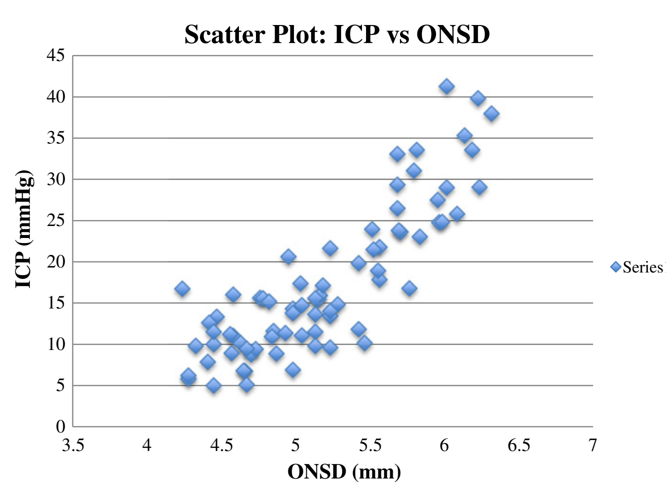

Fig. 1. Scatter Plot 1: ICP vs ONSD. Scatter plot of 75 measurements of ICP in the X axis against the ONSD value in the Y axis. Generally this scatter plot shows a linear relationship. However towards the extreme end of ICP value, the ONSD value started to reach a plateau phase. This is due to maximal dilatation of the optic nerve sheath despite elevation of ICP. Prior studies suggested that with increasing ICPs there might be a maximum nerve sheath diameter that would create an asymptotic relationship. A scatterplot of ICP as a function of ONSD demonstrates this relationship with the maximum ONSD in this population of 6.31 mm.

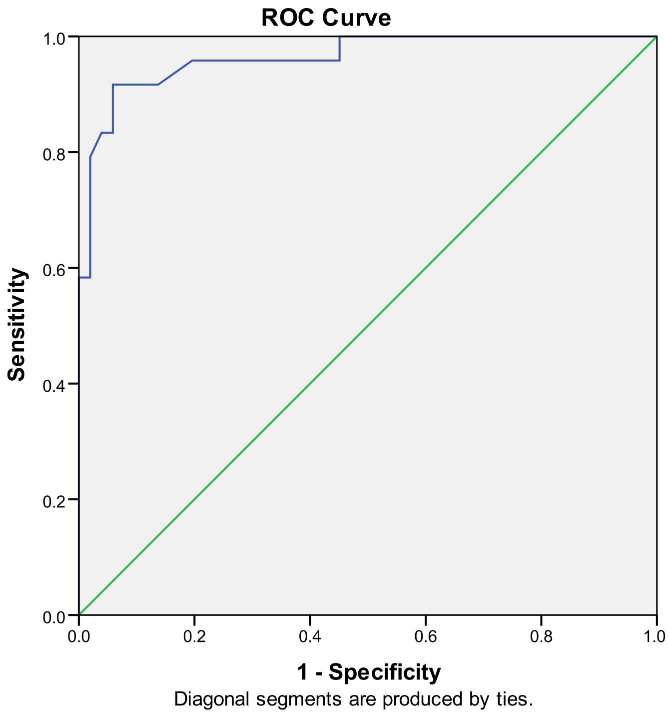

Fig. 2. Receiver operating characteristic curve (Trauma and Non-Trauma Group). The figure above shows a ROC curve, which was constructed to determine the cut-off point to determine high ICP. High ICP was defined as ICP >20 mmHg.

ROC curve, we found that the ONSD value of 5.205 mm is 95.8% sensitive and 80.4% specific in detecting raised ICP. When this ROC curve is analyzed separately to assess the Traumatic and Non-Traumatic group, we found that the overall sensitivity and specificity of ONSD measurement in predicting raised ICP is higher in the Traumatic group compared to Non-traumatic group. For example ONSD of 5.47 mm in the Traumatic group would yield 94.4% sensitivity and 95.2% specificity, whereas the Non-Traumatic group would only yield 83.3% sensitivity and 93.3% specificity in predicting raised ICP (see Table 1).

4. Discussion

Despite the lack of level 1evidence from randomized control trials, the placement of invasive intracranial catheter for ICP monitoring is still recommended for the management of patients with suspected raised intracranial pressure [14]. Many authors in recent publications agree that placement of invasive catheter for the purpose of intracranial pressure monitoring can be considered as the standard of care in managing patients with raised intracranial pressure, especially in traumatic brain injury patients [13-15]). This is in spite of recently published 'Benchmark Evidence from South American Trials: Treatment of Intracranial Pressure' trial or the BEST:TRIP trial, which concluded that management based on invasive intracranial pressure monitoring was not superior to aggressive medical management based on clinical examination and imaging alone. Similarly, The Indications for Intracranial Pressure Monitoring published in Journal of Neurotrauma by the Brain Trauma Foundation, The American Association of Neurological Surgeons recommended this invasive catheter for ICP monitoring in the management of severe traumatic brain injury patients.

The placement of invasive intracranial catheter, either intraparenchymal or intraventricular allows accurate measurements of intracranial pressure. However, being an invasive technique, this procedure is not without its risk. Due to lack of a more reliable and reproducible non-invasive technique to measure ICP, this invasive catheter will continue to be the technique of choice in monitoring patients with suspected raised intracranial pressure.

Our study aimed to find a correlation between bedside ultrasound measurements of optic nerve sheath diameter with this gold standard direct invasive intracranial pressure measurements. Our findings have confirmed prior literature findings that correlate ONSD measurements with ICP measurements.

The technique used in determining the sonographic measurement of optic nerve sheath diameter in our study were similar to the standard technique described by Ballantyne et al [10], published in European Journal of Ultrasound in 2002, and Kimberly et al [4], published in Academy Emergency Medicine in 2008. They describe that using the 7 MHz linear ultrasound probe, an axial image of the optic nerve was obtained. The optic nerve is hypoechoic and is surrounded by retrobulbar fat which are hyperechoic. Optic nerve sheath diameter is measured at this echogenic margins, at 3 mm behind the optic nerve head. Similar techniques were used by [7,12] and again in 2011 in their study on finding correlation between ONSD with ICP. In his attempt to define the standard technique in measuring optic nerve sheath diameter by ultrasound, Soldatos et al [12] performed a literature review from 1987 to 2008. The resultant "standard" technique proposed by them [12] were adapted in measuring the optic nerve sheath diameter in this study.

Apart from the previously mentioned usage of linear ultrasound probe, Soldatos et al suggest that the insonation depth is set to 5 to 8 cm, and the transducer should be softly placed over the upper temporal eyelid in an axial plane. This step will provide a transverse view of the globe and the structures of the retrobulbar area, and to obtain the optimum level of contrast between the echogenic retrobulbar fat and the hypoechoic optic nerve complex. The ONSD can then be calculated 3 mm posterior to papilla, and perpendicular to the vertical axis of the scanning place (optic nerve) as the horizontal distance between the two cursors. In our study, we found that this measurement at 3 mm behind the papilla is not only the maximum diameter distension, but also the segment of the sheath features the greatest ultrasound contrast. We also find that because the measurements are very small, zoom mode was helpful in assisting the precise placement of the cursors and the subsequent accurate evaluation of the ONSD.

Our study has shown that ONSD measurement is more sensitive and specific in detecting raised ICP in Traumatic patients. Traumatic group (94.4% sensitive and 95.2% specific) compared to Non-traumatic group (83.3% sensitive and 93.3% specific). We postulated that these findings may be contributed by the speed of progression of the elevation of the ICP. In trauma patients, for example acute extradural or subdural hematoma, the ICP may be elevated in an acute manner. Non-trauma patients, for example patients with intracranial tumors or hydrocephalus may have a more chronic elevation of ICP. Therefore the measurements of optic nerve sheath diameter, which is largely determined by the expansion of the CSF in the subarachnoid space of the optic nerve, may be more reflective in acute pathology of raised intracranial pressure.

Previous study and literature has identified optic nerve sheath diameter of 5 mm as the cut-off point, of which patients would show evidence of raised ICP either clinically or radiologically if the value exceed 5 mm [4].

In our study, based on the ROC curve, ONSD measurement of 4.94 mm would yield 100% sensitivity, but at the expense of much reduced specificity at only 54.9%. The best compromise would be at ONSD

Table 1
Comparing sensitivity and specificity of ONSD value in Trauma and Non-Trauma Group

	Sensitivity	Specificity
Trauma Group		
ONSD - 5.22 mm	94.4%	90.5%
ONSD - 5.47 mm	94.4%	95.2%
Non-Trauma Group		
ONSD - 5.21 mm	100%	76.7%
ONSD - 5.48 mm	83.3%	93.3%

The above table showing Trauma Group appears to have better sensitivity and specificity of ONSD in detecting raised ICP compared to the Non-Trauma Group, when similar ONSD values were compared.

measurement of 5.205 mm which is 95.8% sensitive and 80.4% specific in detecting raised ICP, of which ICP of >20 mmHg is defined as high or raised ICP. Our sub-analysis of trauma and non-trauma group revealed that this bedside sonographic ONSD measurement is more specific and sensitive in assessing patients with traumatic brain injury.

This method can be a useful adjunct to the current gold standard invasive technique. The benefit of having such an adjunct include the usage in the pre-hospital (prior to transferring patient to a neurosurgical unit), at a district or secondary hospital without neurosurgical consult, or the initial hospital period at a tertiary hospital when invasive ICP measurement has not been performed but indirect estimation of ICP can lead modification of treatment.

Currently a neurosurgical unit will receive referral from district hospital and were often given patient's clinical information which includes conscious level (Glasgow Coma Scale score), vital signs and pupillary size. Based on these clinical information along with any radiological findings that are available, the neurosurgeon will then decide on the next course of action.

Information such as the measurement of optic nerve sheath diameter can be valuable additional tool in deciding the severity of the case and the next course of management; either to keep at the referring center, to send urgently to the nearest neurosurgical unit, or even to suggest the general surgeon at the referring center to proceed with an urgent craniotomy. An estimation of the value of intracranial pressure gained from optic nerve sheath measurement is useful in supporting this clinical judgment.

Repeated measurements of the same patients were made, as explained above during fluctuations of ICP. Seventy-five measurements (from 41 patients) were analyzed and were assumed as independent data. However, due to the fact that some data were measured from the same patient, these data might not be truly independent. This could decrease the variance of the ONSD measurement. However, even when we collapsed the data to 41 by averaging all the measurements of each patient, the resulting scatter plot and Spearmen's correlation test revealed significant correlation.

This study was also limited by its small size. A larger trial, possibly multi-center should be done to validate the results. However, a larger multi-center trial might have a slight disadvantage in terms of bias; especially if the portable ultrasound machine is not standardized and large number of observers might increase the inter-observer variation.

5. Conclusion

A reliable and reproducible, non-invasive bedside measurement of optic nerve sheath diameter as a predictor of raised intracranial pressure may have a wide range of application in the clinical management of neurosurgical patients. This study showed that there is a good significant and positive correlation between optic nerve sheath diameter measurements with intracranial pressure value. Furthermore, changes in intracranial pressure can be detected by changes in optic nerve sheath diameter. We have demonstrated that an optic nerve sheath diameter of 5.205 mm is 95.8% sensitive and 80.4% specific in detecting raised ICP, and that this measurement is more specific and sensitive in the assessing patients with traumatic brain injury.

References

[1] Friedman DI, Jacobson DM. Diagnostic criteria for idiopathic intracranial hypertension. Neurology 2002;59(10):1492–5.
[2] Bullock R, Chesnut RM, Clifton G, Ghajar J, Marion DW, Narayan RK, et al. Guidelines for the management of severe head injury. Brain trauma foundation. Eur J Emerg Med 1996;3(2):109–27.
[3] Czosnyka M, Hutchinson PJ, Balestreri M, Hiler M, Smielewski P, Pickard JD. Monitoring and interpretation of intracranial pressure after head injury. Acta Neurochir Suppl 2006;96:114–8.
[4] Kimberly H, Sahah S, Marill K, Noble V. Correlation of optic nerve sheath diameter with direct measurement of intracranial pressure. Acad Emerg Med 2008;15:201–4.
[5] Blaivas M1, Theodoro D, Sierzenski PR. Elevated intracranial pressure detected by bedside emergency ultrasonography of the optic nerve sheath. Acad Emerg Med 2003;10(4):376–81.
[6] Strumwasser A1, Kwan RO, Yeung L, Miraflor E, Ereso A, Castro-Moure F, et al. Sonographic optic nerve sheath diameter as an estimate of intracranial pressure in adult trauma. J Surg Res 2011;170(2):265–71.
[7] Geeraerts T1, Merceron S, Benhamou D, Vigué B, Duranteau J. Non-invasive assessment of intracranial pressure using ocular sonography in neurocritical care patients. Intensive Care Med 2008;34(11):2062–7.
[8] Newman WD, Hollman AS, Dutton GN, Carachi R. Measurement of optic nerve sheath diameter by ultrasound: a means of detecting acute raised intracranial pressure in hydrocephalus. Br J Ophthalmol 2002;86(10):1109–13.
[9] Liu D, Kahn M. Measurement and relationship of subarachnoid pressure of the optic nerve to intra- cranial pressures in fresh cadavers. Am J Ophthalmol 1993;116(5):548–56.
[10] Ballantynea SA, O'Neil G, Hamilton R, Hollman AS. Observer variation in the sonographic measurement of optic nerve sheath diameter in normal adults, European J of. Ultrasound 2012;5:145–9.
[11] Tayal VS, Neulander M, Norton HJ, Foster T, Saunders T, Blaivas M. Emergency department sonographic measurement of optic nerve sheath diameter to detect findings of increased intracranial pressure in adult head injury patients. Ann Emerg Med 2007;49(4):508–14.
[12] Soldatos T, Chatzimichail K, Papathanasiou M, Gouliamos A. Optic nerve sonography: a new window for the non-invasive evaluation of intracranial pressure in brain injury. Emerg Med J 2009;26(9):630–4.
[13] Hartl R, Philip ES. Intracranial pressure is still number 1 despite BEST:TRIP study. World Neurosurg 2013;79:599–600.
[14] Levitt MR, Joshua WO, Kim LJ. Intracranial pressure monitoring in severe traumatic brain injury. World Neurosurg 2013;79:600–1.
[15] Mattei TA. Intracranial pressure monitoring in severe traumatic brain injury: who is still bold enough to keep sinning against the level 1 evidence. World Neurosurg 2013;79:602–4.