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Diagnostics

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

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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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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

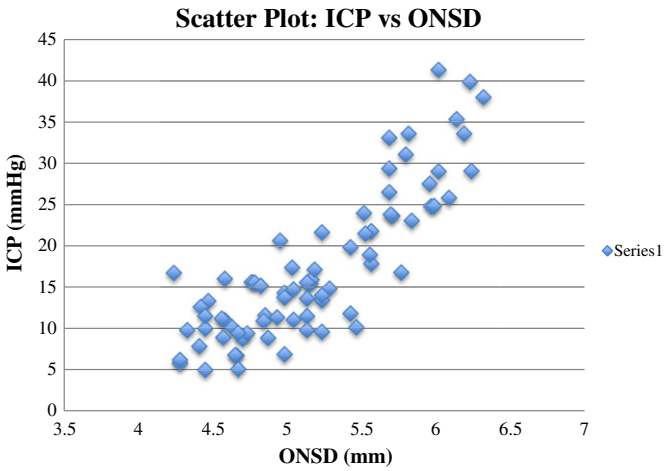

Fig. 1. Scatter Plot 1: ICP vs ONSD. Scatter plot of 75 measurements of ICP in the X axis against the ONSD value in the Y axis. Generally this scatter plot shows a linear relationship. However towards the extreme end of ICP value, the ONSD value started to reach a plateau phase. This is due to maximal 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.