Transorbital Ultrasonographic Measurement of Optic Nerve Sheath Diameter for Intracranial Midline Shift in Patients with Head Trauma

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■ OBJECTIVE: **Measurement of the optic nerve sheath diameter (ONSD) by using sonography is a straightforward, noninvasive technique to detect an increased intracranial pressure, which can even be conducted at the bedside. However, the correlation between ONSD and intracranial midline shift has not been studied.**

■ METHODS: **The authors performed a prospective, blinded observational study in an intensive care unit. Forty-five patients were divided into groups. Of those, 19 patients had a midline shift, whereas 26 had no intracranial pathology or shift and served as control individuals.**

■ RESULTS: **Spearman rank correlation coefficient of difference of ONSD and midline shift was 0.761 ($P < 0.0005$), demonstrating a significant positive correlation between patients with midline shift and control group.**

■ CONCLUSIONS: **Despite small numbers and selection bias, this study suggests that bedside ultrasound may be useful in the diagnosis of midline intracranial shift by measurement of ONSD.**

INTRODUCTION

Head trauma is a critical public health problem throughout the world. There may also be unrecognized changes in patient characteristics and management of neurointensive care (NIC).[1] Patients with head trauma may have hematoma or develop cerebral edema, which can lead to increased intracranial pressure (ICP). Increased ICP leads to poor neurologic outcome in critical care units. Prompt recognition and treatment are essential to prevent possible death. For that reason, periodic evaluation of NIC is important. A reliable, noninvasive means to detect raised ICP is an important issue in the field of neurointensive care. Although papilledema is a long-recognized clinical sign of increased ICP, it can take many hours to weeks to develop.[2] Standard techniques of invasive ICP monitoring, with either an intracerebral probe or an intraventricular catheter, may lead to hemorrhage and infection.[3,4] In addition, it requires neurosurgical expertise[5] and there may be contraindications such as coagulopathy or thrombocythemia.[6,7] In the absence of invasive monitoring, some signs such as edema and the presence of midline shift in computed tomography (CT) and magnetic resonance (MR) may be suggestive of increased ICP,[8] although it is not always an easy task to take CT or MRI in the intensive care unit (ICU) setting[8] because these techniques need acquisition times and require patient transport, which may be harmful for patients of ICU.[9] Although bedside optic nerve sheath diameter (ONSD) ultrasound (US) is known to be a sensitive screening test for elevated ICP in adult head injury, the diagnostic accuracy of ONSD US for intracranial midline shift remains unstudied. We sought to determine the feasibility of ONSD US as a screening tool for the evaluation of midline intracranial shift in the ICU. To our knowledge, this is the first prospective study about this subject.

MATERIALS AND METHODS

Study Design

This was an observational study using a convenience sample of patients with head trauma presenting to an ICU between January

Key words
- Intensive care unit
- Intracranial midline shift
- Optic nerve sheath diameter
- Transorbital ultrasound

Abbreviations and Acronyms
GCS: Glasgow Coma Scale
ICP: Intracranial pressure
ICU: Intensive care unit
NIC: Neurointensive care
ONSD: Optic nerve sheath diameter
TBI: Traumatic brain injury
US: Ultrasound

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Citation: World Neurosurg. (2016) 85:292-297.
http://dx.doi.org/10.1016/j.wneu.2015.10.015

Journal homepage: www.WORLDNEUROSURGERY.org

Available online: www.sciencedirect.com

2014 and June 2015. This study was approved by the participating university's institutional research ethics committee and performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants or relatives. Exclusion criteria included eye injury or facial trauma, a history of elevated intraocular pressure, or eye disease that would reasonably preclude sonographic evaluation of the optic nerve. Patients were divided into groups. Of those, 19 patients had midline shift due to head injury, whereas 26 had no intracranial pathology or shift and served as control individuals. Initially, brain-injured patients were evaluated clinically GCS (Glasgow Coma Scale). All patients underwent CT and synchronous ONSD measurements by optic nerve sonography. A CT finding defined as indicative of ultrasonographic measurement of ONSD for patient group was the presence of mass effect with a midline shift. Patients in the control group were also admitted with head injury. Cranial CT scans were obtained to exclude an intracranial pathology. In this group, there was no midline shift.

TECHNIQUE OF OPTIC NERVE SONOGRAPHY

Bedside, blinded ONSD measurements were performed after patients were admitted to the ICU. A 7.5-MHz transducer by bedside US (Fazone CB, Fujifilm, Greenwood, South Carolina, USA) was used for measurement of ONSD. The examiner scanned both eyes through closed eyelids in supine position. A thick layer of ultrasound gel was used to prevent pressure from being exerted on the eye. The probe was placed on the superior and lateral aspect of the orbit against the upper eyelid with the eye closed and angled slightly caudally and medially until the optic nerve was visualized as a linear hypoechoic structure with clearly defined margins posterior to the globe. Placement of the transducer was adjusted to bring the best angle for displaying the exit of the optic nerve from the globe. The position of the probe was adjusted to clearly display the entry of the optic nerve into the globe. The widest visible retrobulbar ONSD was measured at a point 3 mm posterior to the posterior scleral surface of the globe using an in-built electronic caliper to the nearest millimeter, with an angle perpendicular to the eye ball. All measurements were made bilaterally. Because it was hypothesized that unilateral lesions most likely transmit pressure to parenchymal tissue on the same side, correlation of ONSD to midline herniation was performed separately for unilateral and then bilateral brain injuries. The optic disc was also evaluated by ophthalmoscopy by the senior author (H.F.).

Statistical Methods

Data were analyzed using the statistical package for the social sciences version 16 (SPSS Inc., Chicago, Illinois, USA) and Stata/IC 10.0 (Stata Corporation, College Station, Texas, USA) statistical software. Difference of ONSD between patient and control group were compared. A correlation test for midline shift and ONSD difference was performed. Variables were assessed with the one-way ANOVA test.

RESULTS

Forty-five patients underwent transorbital ultrasonographic ONSD measurement. The average time to ocular ultrasound completion was 6 minutes. Overall, there were 32 men and 13 women. The mean age was 56.5 years (standard deviation 13.64, range 29–93). Spearman rank correlation coefficient of difference of ONSD and midline shift was 0.761 ($P < 0.0005$), demonstrating a significant positive correlation between patient with midline shift and control group (Table 1). The one-way ANOVA test showed that ONSD was significantly different between Group 1 (patient group) and Group 2 (control group) ($P = 0.09 < 0.05$). In 14 patients (73.7%), mean ONSD was larger on the same side with the intracranial lesion than the opposite side. Table 2 shows fundus and shift cross tabulation of patient group. Papilledema was not seen in 4 patients despite the presence of a 6- to 10-mm midline shift. Table 3 shows the cross tabulation of ONSD and midline shift. Figure 1 shows a CT scan of a patient with left hemisphere cerebral edema with a 10.8-mm midline shift. Differences in left and right ONSD of the same patient are seen in Figure 2. ONSD of the left eye is 4 mm larger than the right side.

DISCUSSION

Traumatic brain injury (TBI) is one of the major contributors to death and disability globally.[10-13] The assessment of injury severity and prognosis are of primary concern in this kind of injury.[14] Intracranial pressure monitoring is a cornerstone in patients with cerebral herniation and TBI.[11,15-17] However, currently its usefulness has been questioned.[18-20] The concept of focused US arose 7 decades ago.[21] In 1996, Helmke and Hansen reported a study about the evaluation of the optic nerve sheath expansion under intracranial hypertension by transorbital sonography.[22] Today, ONSD measurement using ocular US is a useful method for indirect assessment of ICP without specific contraindication. This technique was developed on the basis of ocular anatomy. The optic nerve is an outward form of the diencephalon during embryogenesis, wrapped by a nerve sheath that is derived from 3 layers of meninges and protrudes toward the orbit.[23,24] As a consequence of this communication, cerebrospinal fluid (CSF) can transfer freely between the intracranial and intraorbital subarachnoid space.[25] Despite the recent developments in technology,[26-29] midline intracranial shift is one of the main complications associated with brain injury, leading to high morbidity and mortality. For that reason, the early prediction of midline intracranial shift in a neurointensive care unit is an important problem. We found that midline shift led to asymmetric enlargement of ONSD, which was significantly different between patient and control groups. In addition, fundus and shift cross tabulation of the patient group showed that papilledema was not seen in 4 patients despite the presence of a 6- to 10-mm midline shift. For that reason, the measurement of ONSD in neurointensive care is important to identify subclinical cases with midline shift and increased ICP secondary brain injury and to allow prompt treatment.

VALUE OF PRESENT STUDY

The intracranial space has a limited ability to compensate for extra volume caused by cerebral edema occurred by TBI. When the