ACCURACY OF OPTIC NERVE SHEATH DIAMETER MEASUREMENT BY EMERGENCY PHYSICIANS USING BEDSIDE ULTRASOUND

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Abstract—Background: Ultrasound (US) measurement of the optic nerve sheath diameter (ONSD) has been utilized as an indirect assessment of intracranial pressure. It is usually performed by trained ultrasonographers.

Objectives: To evaluate whether or not emergency physicians (EP) are capable of measuring the ONSD accurately by US.

Materials and Methods: A retrospective measurement of ONSD was conducted on computed tomography (CT) scans of the head or facial bones. These patients had undergone ocular US performed by EPs prior to CT scanning. The CT scan measurements of ONSD read by a board-certified radiologist were compared with that of the US read by a registered diagnostic medical sonographer. A difference in measurements of the ONSD $0.5$ mm between the two modalities was considered as significant for this study. Results: The ONSD measurements were performed with CT scan and compared to that of the US. Of the 61 patients studied, 36 (59%) were male and 25 (41%) were female. The average age was $56 \pm 17$ years. All but 3 patients had ONSD measurements that were between 5 and 6 mm. Discrepancy in measurements of the ONSD between US and CT for both groups fell within our predetermined value (0.5 mm) for the majority of cases. None of the measurements were above 6 mm. The intraclass correlation coefficient was 0.9 (95% confidence interval 0.8846–0.9303). Conclusion: Emergency physicians were capable of accurately measuring the ONSD using bedside US. Prospective studies with a larger sample size are recommended to validate these findings. Published by Elsevier Inc.

Keywords—emergency physician; ocular ultrasound; optic nerve sheath diameter; CT scan; ICP

INTRODUCTION

Bedside ultrasound has gained tremendous popularity in most emergency departments (EDs), and it has been integrated as a core element of resident training. Bedside ocular ultrasonography has been used for detection of ocular trauma, retinal detachment, intracranial pressure (ICP), and vitreous hemorrhage in the ED (1–7). Ultrasound measurement of optic nerve sheath diameter (ONSD) has been validated as an indirect assessment of the ICP when performed by formally trained ultrasonographers. Measurements of ONSD by magnetic resonance imaging (MRI) have been shown to correlate with direct ICP measurements (8–10). Our group has recently shown that ONSD measured by computed tomography (CT) was comparable to ONSD measurements by MRI (11).

In terms of its embryonic development, the optic nerve is a part of the central nervous system rather than a...
peripheral nerve. It is derived from an outpouching of the brain (diencephalon) during embryonic development. The optic nerve migrates to the orbit and is ensheathed in all three meningeal layers (dura, arachnoid, and pia mater), known as the optic nerve sheath (12–14). The optic nerve sheath is contiguous with the subarachnoid space, and cerebrospinal fluid flows freely between the cranium and orbit within the subarachnoid space. Increased pressure within the cranium is transmitted to the optic nerve sheath and may be detected by increased size of the ONSD (12,15,16). The normal ONSD is < 5 mm, and anything above 6 mm is considered to reflect a clinically significant increase in ICP (8,9). Measurements between 5 and 6 mm require clinical correlation.

Intracranial pressure is traditionally measured using invasive procedures such as lumbar puncture and ventriculostomy. The most simple and longest-standing method of measuring ICP is to perform a lumbar puncture and to observe the opening pressure. This indirect and imprecise procedure is still commonly used. It has significant disadvantages and inaccuracies. Ventricular catheterization remains the gold standard for ICP measurement today. Both procedures are associated with a high risk of infection, which limits the duration of such monitoring, and with technical difficulties in cannulating a compressed or deviated ventricle in situations of raised ICP (17–19). Bedside ultrasound offers a simple, fast, and indirect assessment of the ICP by measuring the ONSD noninvasively (4,8,20–22). The correlation between the ONSD and direct measurement of the ICP was shown recently (23). MRI measurements of ONSD have been used to detect increased ICP indirectly (8–10). Likewise, bedside ultrasound (US) of the ONSD has been frequently used in recent years to detect ICP (24–27). We have recently shown the correlation of ONSD measurement by CT and MRI, an imaging modality that has been correlated to direct ICP measurement. A correlation between ONSD measurements by CT and by US performed by emergency physician has not been demonstrated, to the best of our knowledge.

This partly retrospective study investigated whether or not emergency physicians (EPs), after a short introductory course on ocular ultrasonography by an EP who is a registered diagnostic medical sonographer (RDMS), are capable of measuring the ONSD as accurately by US as CT scan measurement of ONSD by a board-certified radiologist.

**MATERIALS AND METHODS**

We conducted a retrospective measurement of ONSD on CT scan of patients from the ED and compared the measurements with that of the US. These patients required CT scan of the head or facial bones for medical reasons. These patients had undergone ocular US examination after obtaining a verbal consent. The ocular US, as part of US curriculum, was performed by EPs on all patients evaluated in the ED prior to the CT scan. Participating EPs had received a structured didactic/cognitive training US education comprised of lectures, videotape review, and structured reading from ultrasonography textbooks and journal articles on ONSD US provided by an EP who is an RDMS. Participating physicians did five practice ocular scans under supervision initially. Out of all physicians who had the above training, two attending physicians, four postgraduate year (PGY) level 2 and one PGY level 1 residents performed the ocular US examination for the study. A waiver to review the CT scans was obtained from the institutional review board for this study. The readily available LOGIQ e Ultrasound machine from General Electric (GE Healthcare, Little Chalfont, UK) with a high-frequency 7.5–10-MHz or higher linear array ultrasound transducer was used for imaging. The scans were reviewed for technical adequacy by RDMS. Subjects were put in supine position (head of bed 0°). The probe was placed lightly over each closed eye after covering each eye with Tegaderm (3M, St. Paul, MN), over which the ultrasound gel was applied. Eye structures were imaged while asking the subjects to look forward with closed eyes to align the optic nerve directly opposite to the probe. The ONSD was measured 3 mm behind the optic disc in both transverse and sagittal planes. The average of the three measurements was recorded. A distance (depth) of 3 mm behind the globe was chosen for two reasons. First, the ultrasound contrast is greatest/the results more reproducible, and secondly, because changes in ONSD with ICP are greatest at this level (5,6,28,29). In the absence of complete visualization of the entire optic nerve, the largest viewed diameter was taken as the maximal ONSD (Figure 1A–C). Prior experience of EPs ranging from very limited to quite extensive experience with US was not controlled for in the study. The ONSDs on the US were read by the RDMS EP retrospectively. The results of the ONSD measured by US were compared with the measurements from CT scan of the head or facial bones read by a board-certified radiologist (Figure 1D–F). Measurements of ONSD on CT scan were performed using an electronic caliper on a Sectra Workstation, Pictorial Archiving and Communication System (PACS; Sectra Imtec AB, Teknikringen 20, SE-583 30 Linköping, Sweden). The same radiologist also reviewed the scans for additional abnormalities within the orbit. A discrepancy of 0.2–0.7 mm in ONSD measurements has been reported (30,31). For our study, we considered a difference in ONSD measurements of ≥ 0.5 mm between the two modalities as a significant discrepancy.
STATISTICAL METHODS AND ANALYSIS

A mixed linear model was constructed, with measurement mode (US vs. CT) introduced as a fixed effect and subjects as a random effect estimated separately for each mode. Intrapatient variance (IPV) was modeled separately for each combination of mode (CT, US) and locus (left eye sagittal plane [LEYESAG], left eye transverse plane [LEYETRA], right eye sagittal plane [REYESAG], right eye transverse plane [REYETRA]) with a one-way random effects model. Intraclass correlation coefficients (ICCs) were constructed for each mode separately and across modes, using an absolute-agreement framework. The measurements of ONSD were compared for correlations and agreement between the two modalities using MedCalc Software (Version 12.7.0, Acacialaan, B-8400 Ostend, Belgium) according to the method by Bland and Altman (32–34).

RESULTS

The CT scans of 61 patients who had ocular US for educational purpose was reviewed for ONSD. A total of 61 patients had ocular US and were included in the study. Of these 61 patients, 36 (50%) were male and 25 (41%) were female. The average age for all patients
was 56 ± 17 years. Thirty-nine patients (64%) were Hispanic (21 male, 18 female), 15 patients (24.6%) were black (9 male, 6 female), 6 patients (9.8%) were white (5 male, 1 female), and 1 patient (1.6%) was Asian.

All but 4 patients’ ONSD measurements were above 5 mm but below 6 mm. None of the measurements were above 6 mm. Discrepancy in measurements of the ONSD between US and CT for both planes fell within the predetermined cutoff value of 0.5 mm for the majority of the cases. Only 3 of 61 patients with facial trauma (5%) have discrepancies more than the predetermined cut-off value. The correlations and agreement between the two measurements (US and CT) are plotted in Figures 2 and 3.

IPV was modeled separately for each combination of mode (CT, US) and locus (LEYESAG, LEYETRA, REYESAG, REYETRA) with a one-way random-effects model. If values fell within our predetermined cutoff (0.5 mm), we considered bedside ocular US as a suitable supplement to the standard technique, CT scanning. The correlation coefficient $R$ for CT vs. US = 0.8413, $p$-value < 0.0001, and 95% confidence interval for $r$ = 0.8002–0.8745. Correlation coefficient $R$ for CT vs. US in sagittal plane was 0.8306, the $p$-value < 0.0001 and 95% confidence interval for $R$ = 0.7660–0.8787. The correlation coefficient $R$ for CT vs. US in transverse plane was 0.8520, $p$-value < 0.0001 and 95% confidence interval for $R$ = 0.7946–0.8943. Assessment of inter-rater reliability for US was not conducted, as it would require each patient to be measured by two or more operators. The ONSD measurements of each patient were completed by only a single EP.

The ICC for both the transverse and sagittal plane measurements were > 0.9, suggesting very high concordance between the two techniques. The ICC does not provide information about the magnitude of the difference between the two measurement techniques. Rather, it provides a scalar measurement of concordance between the two methods. ICC can be interpreted as follows: 0–0.2 indicates poor agreement; 0.3–0.4 indicates fair agreement; 0.5–0.6 indicates moderate agreement; 0.7–0.8 indicates strong agreement; and > 0.8 indicates optimal agreement.

**DISCUSSION**

The number of potential uses of ocular US is growing. Ultrasonography may greatly aid EPs in avoiding lengthy consultations or other diagnostic studies. It is noninvasive and can be done at the bedside (2,24–26,35–37). The eye is ideal for ultrasonography as it is fluid-filled, enabling visualization of ocular structures. Orbital structure, globe, lens, retina, and retro-ocular hematomas can all be visualized using ultrasound (38).

When evaluating a new measurement technique (US) that compares a clinically accepted method like CT scanning, the degree of “agreement” is a practical gauge. The two methods can be used interchangeably if agreement is
within statistical limit. Our results demonstrate that EPs were capable of accurately measuring the ONSD at the bedside using ultrasound after a brief training session. No significant discrepancies were noted when comparing the measurements of ONSD using US to that of the CT except the three cases. The differences in the measurements obtained by EPs were within an acceptable range and would not have caused a significant miss.

Other pathologies detected by ultrasonography of the orbits included prominent papilla in the left eye in a patient who presented with left leg weakness, blurry vision in his left eye, and ptosis after a fall. CT scan and CT angiogram of the brain to rule out vertebral or internal carotid artery dissection was unremarkable. The possibility of multiple sclerosis was entertained, but the patient left against medical advice before the MRI study was done. Another patient who presented with frequent falls had vitreous hemorrhage in her right eye.

Ocular ultrasonography provides a rapid and cost-effective method of ONSD measurement and an indirect measure of ICP. Results of this study indicated that EPs with a basic understanding of US principals and a short introductory course in ocular US can accurately image the ONSD, as compared to CT scan measurements read by a board-certified radiologist. The two techniques demonstrate significant concordance, warranting further study in a larger population of patients with normal ICP and confirmation in patients with clinical findings highly suspicious of elevated ICP. Further verification of this bedside US technique may demonstrate its utility in the
rapid diagnosis and treatment of patients with elevated ICP prior to lumbar puncture or CT scanning in the ED. Ultrasound may also help diagnose other conditions that are not related to increase in ICP but may mimic some of the symptoms. Such conditions include retinal detachment, vitreous hemorrhage, and papilledema that may be missed by CT scan. In addition, it can be used as a fast and simple bedside tool prior to procedures like lumbar puncture, pupillary light reflex, and extracocular movements for head and facial trauma patient with ocular injuries. Bedside ocular US can also be a useful test in patients with preeclampsia for whom CT scan might not be an ideal imaging test due to radiation exposure to the fetus to assess for signs of increased ICP (26,37).

Limitations
The study is limited by a small sample size and ONSD measurements that were, in the majority of the cases, within normal limits. Ultrasound measurement is operator dependent and the study is limited by the lack of interpersonal variability. The study is also limited in scope because it only included patients who received a head or facial bone CT scan. Other limitations encountered were the initial learning curve to identifying proper landmarks for US placement on the patient, identifying the edges of the optic nerve sheath on US images, and patient compliance with the procedure. These difficulties may account for some of the outlying measurements in the study. In addition, individual extracurricular practice, prior experience, as well as PGY level were not subclassified for analysis.

CONCLUSION
Emergency physicians were capable of accurately measuring the ONSD at the bedside using US after a brief training session. Accurate measurement of the ONSD at the bedside, if validated by future prospective studies using ED ultrasound, can be utilized as a quick and cost-effective method of indirectly measuring the ICP in conditions such as preeclampsia, ocular trauma, head trauma, and lumbar puncture.

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REFERENCES


ARTICLE SUMMARY

1. Why is this topic important?
   Fast and reliable measurement of intracranial pressure (ICP) noninvasively is of paramount importance in cases of trauma or other conditions such as idiopathic ICP. Ultrasound can help in this condition at the bedside.

2. What does this study attempt to show?
   The study attempted to show that bedside ultrasound (US) could be utilized to measure optic nerve sheath diameter (ONSD).

3. What are the findings?
   The study showed that ONSD can be measured using bedside US and results were similar to that of the computed tomography scan results.

4. How is patient care impacted?
   This study suggests that bedside US can rule out increased ICP fast and noninvasively.