Correlation of optic nerve sheath diameter measurements by computed tomography and magnetic resonance imaging

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Abstract

Background: Traditionally, intracranial pressure is measured by direct ventriculostomy, which is invasive. Noninvasive measures such as bedside ultrasound and magnetic resonance imaging have been advocated and utilized recently to assess the intracranial pressure. The role of this study is to determine the degree of agreement between measurements of the optic nerve sheath diameter by computed tomography (CT) and magnetic resonance imaging (MRI).

Materials and Methods: Retrospective chart review of 100 consecutive patients who had both MRI and CT scan of the head from January 1, 2011, until March 31, 2013, at our center was performed. A discrepancy of 0.2 mm between the 2 measurements was set as acceptable difference. The measurements of optic nerve sheath diameter (ONSD) were compared for agreement between the 2 modalities using the method by Bland and Altman.

Results: A total of 100 patients with both MRI and CT scan of the head were selected. Of these 100 patients, 24 were male and 76 were female. The average age was 63 years. No ONSD abnormality was detected in any of the patients. The discrepancy in measurements of the ONSD between CT and MRI in transverse plane was less than the predetermined cut-off value of 0.2 mm. Within-subject variance was estimated at 0.0058 for both CT and MRI.

Conclusion: Comparable results without significant discrepancy as predetermined by the study groups were obtained from CT scan. Measurement of ONSD by CT scan can be used to indirectly assess the intracranial pressure in addition to clinical assessment and other signs of increased intracranial pressure on CT scan.

The purpose of this study is to compare measurements of the ONSD by CT, a diagnostic modality that is obtained frequently, and MRI. If an agreement exists between MRI and CT measurements, CT scan could be utilized as an additional indirect method for assessing ICP.

1. Introduction

Optic nerve sheath diameter (ONSD) has been used to indirectly assess the intracranial pressure (ICP) [1–4]. Traditionally ICP measurement was done by direct ventriculostomy which is the gold standard, but this test is invasive and associated with some procedure risks such as infection and technical difficulties [5–9]. Other indirect signs of increased ICP determined by computed tomography (CT) scan such as ventricle size, basilar cistern size, sulci size, degree of trans-falcine herniation, and gray/white matter differentiation [10,11] have been unreliable [12]. Recently, noninvasive measures such as bedside ultrasound and magnetic resonance imaging (MRI) have been advocated and utilized to assess the ICP. Indirect measurement of ICP by determining ONSD using MRI has been found to reliably correlate with direct ICP measurement [13–15]. There has been no study so far comparing CT scan measurements for ONSD with direct ICP measurement to the best of our knowledge.
the scans for additional abnormalities within the orbit. The ONSD is measured at 3 mm behind the globe for both modalities (Fig. 1). Patient demographics and all ONSD measurements were recorded and compared. A waiver for informed consent was obtained from the institutional review board prior to the inception of the study.

A discrepancy of 0.2 to 0.7 mm in ONSD measurements has been reported [16,17]. We set the smallest discrepancy of 0.2 mm as an acceptable difference between the two modalities arbitrarily. A mixed linear model was constructed, with measurement mode (CT vs MRI) introduced as a fixed effect, subjects as a random effect estimated separately for each mode. Residual (within-subject) variance was also estimated separately for each mode. Intraclass correlations were constructed for each mode separately and across modes, using an absolute-agreement framework. The measurements of ONSD were compared for 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 [18–20].

3. Results

A total of 100 patients with both MRI and CT scan of the head were selected. Of these 100 patients 24 were male and 76 were female. The average age was 63 years (average age for male 60 years and for female 64 years). The time between CT and MRI in general varied from hours to days depending upon the clinical scenario.

The measurements of ONSD in both modalities were within normal limits for all patients. The discrepancy in measurements of the ONSD between CT and MRI for transverse plane was less than the predetermined cut-off value of 0.2 mm. The agreement between the two measurements (CT vs MRI) is plotted in Fig. 2. This technique focuses on the differences between the two measurements. First, the measurement in the transverse plane is plotted along the x-y axis (Fig. 1). If measurements are comparable, they should cluster tightly around the line of equivalence. Second, the difference between the measurements (CT scan diameter minus MRI diameter) are plotted (Fig. 2) against their means [(CT scan diameter + MRI diameter)/2]. If the differences between the 2 techniques are small, the plot should center near zero, demonstrating minimal variation in regard to the mean of the measurement pairs. If values fall within our predetermined cutoff (0.2 mm) then we will consider the comparative technique suitable as a substitute or supplement to the standard technique (correlation coefficient $r = 0.8941$, $P < .0001$ and 95% confidence interval for $r$ 0.8624-0.9189). The confidence interval is calculated for the mean difference and the intra-class correlation coefficient (ICC) is determined. All measurements in the transverse plane fell within our pre-determined significance cutoff of 0.2 mm and these pre-determined cutoffs corresponded well with the 2-SD cutoff values. The ICC for the transverse plane measurements were 0.89 (95% confidence interval 0.8617-0.9184), suggesting optimal concordance between the two techniques. Within-subject variance was estimated at 0.0058 (SE=0.0006) for CT, and 0.0058 (SE=0.0006) for MRI. ICC was estimated at 0.93 for CT, 0.93 for MRI, and 0.93 across modes. There was no significant CT vs MRI mean effect ($P = .913$).

General agreement is quite high. The similarity of all these

![Fig. 1. Measurements of ONSD by CT scan. A. Representative CT scan image of the brain with Optic nerve at 3-mm depth measured behind the globe (green arrow). B. Representative CT scan image of the brain with ONSD at 3-mm depth (red arrow).](image)

![Fig. 2. Measurements of ONSD by CT scan and MRI: Correlation (A) and agreement of ONSD measurements with 95% limit of agreement (B).](image)
estimates between modes indicates near-total homogeneity of measurement across measurement modalities.

4. Discussion

Intracranial pressure is traditionally measured using invasive procedures such as lumbar puncture and/or ventriculostomy [6,8]. 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 [6]. Ventricular catheterization remains the standard for ICP measurement today. Both procedures are associated with a risk of infection, which limits the duration of such monitoring, and technical difficulties when cannulating a compressed or deviated ventricle in situations of raised ICP [5-8,21–23]. It has been shown that a correlation between measurements of ONSD by ultrasound and MRI and direct ICP measurements exists [14,15,24]. However, MRI of the brain is not as frequently used for acute conditions when compared to CT. It would be helpful to evaluate the accuracy of the CT scan in directly assessing the ICP in addition to other known CT signs for increased ICP. Our study focused on assessing the agreement between measurements of ONSD by CT and MRI, which has been correlated with direct measurement of the ICP.

In general, when comparing a new measurement method with an old and established technique, it is important to determine whether the two measurement results are close to each other and agree sufficiently for the new method to replace the old one. The results of our study demonstrate that the measurements of ONSD obtained by CT as compared to measurements obtained by MRI were within the pre-chosen margin for acceptable discrepancy of 0.2 mm. In addition, all measurements of ONSD by both MRI and CT were less than 5 mm, the acceptable upper normal limit for ONSD.

In general, non-invasive assessments of ICP do not obviate the need for invasive monitoring. Invasive monitoring detects changes of ICP continuously whereas non-invasive measurements are randomly done and at interval. In addition the direct measurement techniques offer therapeutic option such as intraventricular drainage of cerebrospinal fluid. However, noninvasive screening tests may be useful in select populations who would not otherwise require invasive monitoring and could undergo CT or MRI scans, such as patients with liver failure, meningitis, stroke, and moderate traumatic brain injury. Access to a reliable noninvasive measure of ICP from a readily available and often ordered imaging modalities such as CT scan could be extremely valuable in the initial evaluation of patients with suspected ICP and guide early appropriate management. The technique could have a role as a screening tool for identification of patients in need of invasive ICP monitoring after moderate head trauma. It could also play a role in diagnosis and evaluation of several chronic disorders potentially associated with increased ICP values such as hydrocephalus, pseudotumor cerebri and intracranial mass lesions.

5. Limitation

The study is limited by its retrospective nature and small sample size and because it only included measurements of ONSD that are within normal limit. The age and gender distribution was not uniform and any age or gender related discrepancy may account for lack of uniformity of the overall measurements. The other limitations are that the measurements are not directly compared with the gold standard (direct ICP measurement) and they are to some extent reader dependent and may vary based on the images selected. Furthermore the time between the imaging modalities compared varied from hours to days. However this limitation may not be of high significance since our subjects had all normal ONSD. A future prospective study of the correlation between CT and MRI measurements of ONSD in a population which include subjects with increased ICP and ONSD would eliminate some of the limitations and further confirm the correlation between these two measurements.

6. Conclusion

Results comparable to MRI were obtained from CT scan measurement of ONSD. Measurement of ONSD by CT scan could be used to indirectly assess the ICP in addition to clinical assessment and other signs of increased ICP on CT scan.

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References: