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CT Evaluation of Optic Nerve Sheath Diameter in Traumatic Brain Injury and its Correlation with Rotterdam CT Scoring

Gautam M[1], Kafle P[2], Pathak MR[1], Devkota G[1], Ranabhat N[1]

[1]Department of Radiology, Nobel Medical College Teaching Hospital, Biratnagar, Nepal
[2]Nobel Institute of Neurosciences, Nobel Medical College Teaching Hospital, Biratnagar, Nepal

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ABSTRACT

Introduction: Elevated intracranial pressure is one of the fatal events associated with traumatic brain injury. Optic nerve sheath diameter measurement is an indirect way of assessing intracranial pressure. Optic nerve sheath diameter and Rotterdam score are prognosticators of traumatic brain injury. This study aimed to measure the optic nerve sheath diameter in the initial CT scan and correlate with the Rotterdam score.

Methods: Retrospective analytical study comprising consecutive patients from July 2019 to December 2019 who underwent decompressive craniotomy for traumatic brain injuries were included. Optic nerve sheath diameter was measured 3mm behind the eyeball in axial images and Rotterdam CT Score was done on the same CT image in another setting. The receiver operating characteristics curve was plotted to measure the accuracy of optic nerve sheath diameter in predicting the severity of traumatic brain injury.

Results: Sixty patients with a mean age of 42.5±14.6years were included. The mean optic nerve sheath diameter with Rotterdam Score of 1, 2 and 3 was 3.8±0.64mm and with Rotterdam Score of 4, 5 and 6 was 5.1±0.66mm. The area under the curve of severe Rotterdam CT Score vs optic nerve sheath diameter was 0.915 ($p<0.0001$, 95% CI 0.84-0.98) and spearman Rho correlation coefficient value was 0.83 suggesting positive relation.

Conclusion: Higher mean optic nerve sheath diameter was observed with a severe Rotterdam CT score. Thus, optic nerve sheath diameter of initial CT scan in traumatic brain injury cases could be an important radiological tool to rule out the presence of raised intracranial pressure.

Keywords: *Brain Injuries; Decompressive Craniectomy; Intracranial Pressure; Optic Nerve*

INTRODUCTION

Traumatic brain injury (TBI) is one of the leading causes of morbidities and mortalities worldwide.[1] The annual incidence is 200-400

Correspondence to: Mahesh Gautam
Department of Radiology
Nobel Medical College Teaching Hospital
Biratnagar, Nepal
Email: mahes.gautam07@gmail.com

cases per 100,000 and is a major contributor to socio-economic costs in underdeveloped countries like Nepal.[2] Majority of them are due to motor vehicle accidents followed by fall injuries and violence.[3]

CT scan is considered as the gold standard in the evaluation of TBI because of its high sensitivity in detecting fractures and hematomas.[4] Based on findings of an initial CT scan, Marshall and Rotterdam CT Score (RCTS) are the two scoring systems used to assess the severity and prognosis of the TBI. In Marshall classification, epidural and subdural lesions are not considered as a separate entity and subarachnoid haemorrhage is not included in the scoring system, Rotterdam CT score is more preferred nowadays.[5] High RCTS is associated with a higher mortality rate and this has been proved in various studies. In a study of adult age group patients, RCTS of 4 and above have the mortality rate ranging from 26-61%.[6,7]

The prognosis in TBI is affected by several factors including age, the severity of the injury and other associated co-morbidities.[8] Elevated Intracranial pressure (ICP) is one of the fatal events associated with TBI. Undiagnosed and late intervention is associated with high mortality.[9] So, measurement of ICP is crucial. The optic nerve is an extension of the central nervous system. It is covered with dura and arachnoid mater containing cerebrospinal fluid.[10] The cerebrospinal fluid (CSF) space around the optic nerve is in continuous to that of the intracranial subarachnoid space. As the intracranial pressure increases, the CSF flow around the optic nerve increased distending the optic nerve sheath thus increased the optic nerve sheath diameter (ONSD). Various studies have suggested ONSD as one of the non-invasive, convenient and indirect ways of measuring ICP.[11] ONSD could be measured using ultrasound, CT and magnetic resonance imaging (MRI). Many studies have shown a positive correlation between ONSD measurement on CT scans with the increased ICP.[12] ONSD and RCTS are known predictors of the outcome of traumatic brain injury. Very few studies have correlated between ONSD in the initial CT scan and RCTS. A study conducted in Tribhuvan university teaching hospital shows about 5% of cases of emergency visits are related to traumatic brain injury which accounts for mortality of 30%.[13] As the literature review shows no such study has been conducted in this part of the country so far. This study aims to measure the ONSD in the presentation brain CT scan of traumatic brain injury, determine the relationship between ONSD and RCTS and correlate with the severity of TBI.

METHODS

This retrospective analytical study was conducted at Nobel Medical College, Biratnagar Nepal. All the consecutive patients from July 2019 to December 2019 irrespective of sex and aged ≥ 18years who had a history of trauma with clinical suspicion of head injury, had undergone CT scan and underwent decompressive craniotomy were included in this study. The patients were enrolled using convenience consecutive sampling. Patients having orbital disease affecting the globe, facial trauma affecting the eyeballs, exophthalmia, known case of systemic disease affecting eyeballs like hyperthyroidism and those incomplete records were excluded. Ethical clearance was obtained from the institutional review committee.

All the CT scans of the patients were assessed for ONSD and RCTS. Two radiologists who were not involved in data collection and were unaware of the patient clinical history reviewed the CT images using Picture Archiving and Communication Software (PACS). Optic nerve sheath diameter was measured according to the standard protocol i.e. 3mm behind the posterior limit of the eyeball in one mm thick slice in axial plane using soft tissue (Chest/abdomen) window. A sagittal plane was used if the measurement was not possible in an axial plane. The diameter of both optic nerve sheath was measured and the mean was obtained. The interobserver variability in the measurement of the ONSD was calculated. Similarly, the CT brain of each patient was scored according to the RCTS by another radiologist.

Data were analyzed using SPSS v.22. Descriptive qualitative data were presented as frequency and percentage values, while descriptive quantitative data were presented as mean, standard deviations and ranges with minimum-maximum values. Based on the score of RCTS; patients were divided into two groups. Those patients with a score of 1, 2 and 3 were labelled as mild head injury and 4, 5 and 6 were labelled as a severe head injury. The comparison between RCTS groups and ONSD was performed using the Mann-Whitney U test. The receiver operating characteristic (ROC) curve was plotted and the accuracy of ONSD was calculated to predict the severity of TBI. The best cut off value was determined and sensitivity, specificity, positive and negative predictive values were calculated. The correlation of RCTS with ONSD value was performed using the Spearman Rho test. A p-value of less than 0.005 was considered significant.

RESULTS

General Demographic Data

During six months 78 traumatic head injury patients were operated in the Neurosurgery department of Nobel Medical College and 60 patients fulfilling the inclusion criteria were included in this study. Out of 60 patients, 73.3% (n=44) were males and 26.7% (n=16) were females. The mean age of the patient was 42.5 ± 14.6years. Motor vehicle accident is the most common mode of injury (68.3%) followed by fall injury (23.3%) and physical assault (8.4%).

ONSD Measurement

The mean optic nerve sheath diameter in this study was 4.1 ± 0.8mm with a range of 3.0 to 6.5mm (Figure:1). The mean optic nerve sheath diameter in the right eye was 4.17mm and in the left eye was 4.09mm. There was no statistical difference in optic nerve sheath diameter measurement in both eyes. (p-value < 0.0001) Interobserver variability of ONSD measurement was calculated and no statistical difference was found with the Interclass coefficient value of 0.957 (Confidence Interval: 0.92-0.97) and p-value < 0.0001.

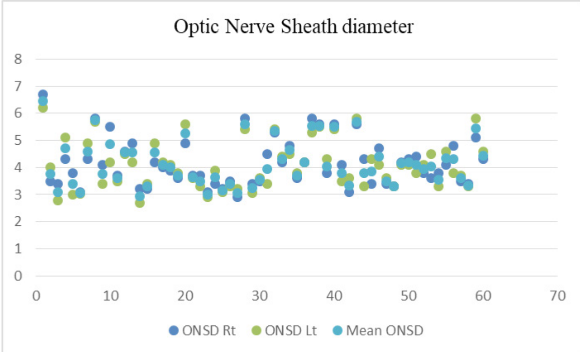

Figure 1: *Optic nerve sheath diameter in traumatic brain injury patients*

RCTS

Out of 60 patients, 13 patients had an RCTS score of 1, 22 patients had a score of 2, 9 patients scored 3, 10 patients scored 4 and 6 patients had a score of 5. 44 patients had mild head injury i.e. RCTS score of 1, 2 and 3 and 16 patients had a severe head injury with RCTS of 4, 5 and 6.

The relation between Severe brain injury and ONSD

The mean optic nerve sheath diameter in patients with RCTS of 1, 2 and 3 was 3.8 ± 0.64mm and with RCTS of 4, 5 and 6 was 5.1 ± 0.66mm. The mean ONSD value for different RCTS is shown in figure 2. The mean ONSD value was higher for higher RCTS which was statistically significant (p < 0.0001). The cutoff value of ONSD for the prediction of severity of traumatic brain injury was calculated with ROC analysis which showed statistical significance for the area under the curve of severe RCTS vs ONSD: AUC of 0.915(p < 0.0001, 95% CI, 0.84-0.98)(Figure 3). The best cut-off value of ONSD was found to be 4.5mm with sensitivity and specificity, negative predictive value and positive predictive value of 93.8%, 97.7%, 99.4% and 24.2% respectively. The correlation between ONSD diameter and RCTS was performed using the Spearman Rho test which showed a correlation coefficient value of 0.83 and a p-value of <0.0001 which are statistically significant values and indicates positive relation between them. Correlation among optic nerve sheath diameter and a different individual component of RCTS, only basal cistern and midline shift showed the significant co-relation value of 0.664 and 0.634 respectively. (Table 1)

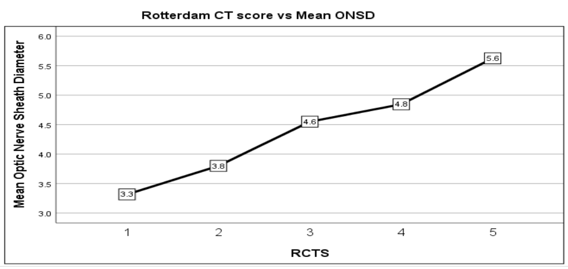

Figure 2: *Graph showing mean ONSD across RCTS*

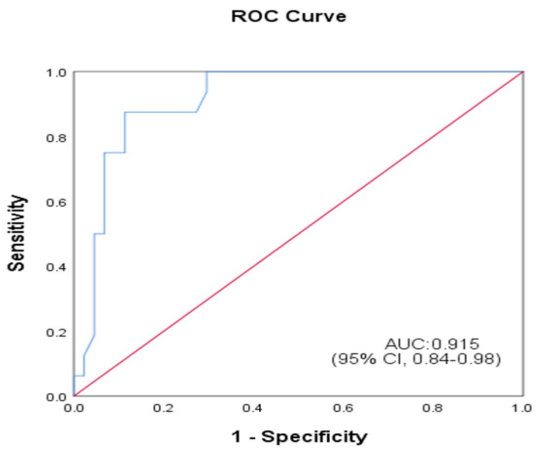

Figure 3: *ROC curve analysis for the relationship between high RCTS and ONSD*

Table 1: Correlation among ONSD and a different component of RCTS

Variables	Spearman co-relation value	p-value
Basal cistern	0.664	<0.001
Midline Shift	0.634	<0.001
Epidural mass lesion	0.004	0.974
Intraventricular/Sub-arachnoid hemorrhage	0.495	<0.001

DISCUSSION

Both Rotterdam CT score and ONSD are the two independent parameters used to predict the outcomes in cases of traumatic brain injury. Very few studies were found where RCTS and ONSD are compared. In this regard, we aimed to evaluate the correlation between the ONSD measurement of initial CT scan with the Rotterdam CT score.

CT is the preferred imaging modality in case of head injury and is easily available in most of the centres. Based on the imaging findings, Marshall CT classification and Rotterdam CT score are used to assess the severity and prognosis of traumatic brain injury. Rotterdam CT score is expressed as a score of one to six and a higher score indicates more severe head injury. Many studies considered RCTS as an independent radiological prognostic tool.[14,15] Raised ICP secondary to traumatic brain injury is an indicator of poor prognosis. Timely diagnosed of raised ICP is crucial for management. Optic nerve sheath diameter measurement is an alternative indirect way of measuring ICP. The correlation between the CT measurement of ONSD and ICP have been established in many studies. A study by Sekhon et al. concluded ONSD as a stronger predictor of raised ICP compared to other CT findings.[16]

In this study, it was found that RCTS showed a positive correlation with the ONSD value. RCTS score of 1, 2 and 3 had lower ONSD value within the normal range whereas RCTS score of 4 and 5 had higher ONSD value. A study by Das et al. also showed a linear relationship between the RCTS scores and mean ONSD value which was similar to this study.[17] No patient with RCTS of 6 was observed in this study. This may be due to the mortality of these severe head injury patients because of the delay in reaching the hospital. The various study showed different cut off value of ONSD. ONSD > 5.8mm is considered to be an indicator of critical traumatic brain injury. A study by Sekhon et al. showed a cut-off ONSD value of 6 mm with an area under curve value (AUC) of 0.83 (95% confidence interval: 0.73-0.94), sensitivity, specificity, the negative and positive predictive value of 97%, 42%, 92% and 67% respectively.[16] In this study ONSD and severity of RCTS showed AUC of 0.915(CI-95%, 0.84-0.98) with best cut off value at 4.5mm and sensitivity specificity, negative predictive value and positive predictive value of 83.1%, 88.6%, 99.4% and 24.2% respectively. If we consider the cut off value of 5.8mm then the ONSD value has a very high specificity of 97.7%. Waqas et al. compared ONSD and RCTS in cases of TBI requiring decompressive craniotomy. Bilateral mean ONSD as a predictor of mortality showed AUC of 0.49 [95% CI: 0.36-0.62] whereas RCTS as a predictor of 30-day mortality showed a significant AUC of 0.67 [95% CI: 0.572-0.820]. Also, the mean ONSD does not significantly differ between survivors and non-survivors.[5] In the study by Soldatos et al. ONSD correlates with a severe head injury and raised ICP. The maximum cutoff of ONSD in the prediction of raised ICP was found at 5.7mm with sensitivity and specificity of 74.1% and 100%.[18] Although, in this study, ONSD measurement was done using ultrasonography but, the results are comparable. This study also demonstrates the accuracy of CT ONSD measurement because of the low inter-observer variability. Similar low inter-observer variability in CT ONSD measurement was also observed in the study by Legrand et al.[12]

The gold standard for measurement of ICP is an external ventricular device which is an invasive procedure and may not be available easily or too expensive to use routinely especially in the context of hospital setting of developing countries. This study does not challenge the standard method of monitoring ICP rather discuss the economical way of monitoring ICP. ONSD should be documented in initial CT scan reports so as we have the baseline value of ONSD. Subsequently, ONSD could be measured using ultrasonography and increased ONSD suggests increase ICP so as appropriate management plan could be taken. There are a few limitations in this study. First of all, data were retrospectively collected from a single centre so, the sample size may be considered to be small despite all the consecutive patients who were admitted and operated in this institute were included. Secondly, no correlation was done with clinical outcome. No control group was included to document the normal ONSD. Despite having these limitations, we strongly believe that this study provides useful information regarding the importance of documenting ONSD in the initial CT scan report of traumatic brain injury patients along with other parameters of RCTS. In future, a prospective study including ONSD measurement on CT and its correlation RCTS and the clinical outcome along with ONSD measurement after the neurosurgical intervention may be required. Simultaneous measurement of the ONSD with ultrasound or magnetic resonance imaging may be required to further validate the CT measurements of ONSD.

CONCLUSION

This study shows an increase in mean ONSD with an increase in RCTS which is indirect evidence of raised intracranial pressure. Thus, CT ONSD should be documented in each report of the initial CT scan of traumatic brain injury cases which may be an important radiological tool to rule out the presence of raised intracranial pressure.

CONFLICT OF INTEREST

None

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None

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