

# Optic nerve: measure the diameter of its sheath to detect intracranial hypertension

## *Nervo óptico: medida do diâmetro de sua bainha para detectar hipertensão intracraniana*

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### ABSTRACT

**Objective:** This work had the objective of reviewing the literature on the evaluation and detection of intracranial hypertension through optical nerve ultrasound. **Method:** literature review based on a bibliographic survey in the electronic databases: PubMed, LILACS, SCIELO and CINAHL, using the following descriptors: Intracranial Hypertension, Optic Nerve, Ultrasonography, its correspondents in Portuguese and their intersections. We selected 27 articles published in the period of 1998-2017. **Results:** the articles indicated that ultrasonography of the diameter of the optic nerve sheath (ONSD) is useful in the detection of intracranial hypertension. **Conclusion:** The increase in ONSD is a highly accurate change to diagnose increased intracranial pressure in critically ill patients.

**Keywords:** Intracranial hypertension; Optic nerve; Ultrasonography

### RESUMO

**Objetivo:** este trabalho teve como objetivo realizar uma revisão da literatura sobre a avaliação e detecção da hipertensão intracraniana através da ultrassonografia do nervo óptico. **Métodos:** revisão narrativa da literatura baseado em um levantamento bibliográfico nas bases de dados eletrônicas: PubMed, LILACS, SCIELO e CINAHL, através do uso dos descritores: Intracranial Hypertension, Optic Nerve, Ultrasonography, seus correspondentes em português e suas intersecções. Foram selecionados 27 artigos publicados no período de 1998-2017. **Resultados:** os artigos indicaram que a ultrassonografia do diâmetro da bainha do nervo óptico (DBNO) é útil na detecção da hipertensão intracraniana. **Conclusão:** O aumento do DBNO é uma alteração com elevada acurácia para diagnosticar o aumento da pressão intracraniana em pacientes críticos.

**Descritores:** Hipertensão intracraniana; Nervo óptico; Ultrassonografia

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## INTRODUCTION

The ultrasound is a safe and effective form of imaging that has been used by doctors for over half a century to help in the diagnosis and to guide in the procedures. In 2004, an ultrasound conference made by the American Institute of Ultrasound in Medicine (AIUM) came to the conclusion that the concept of “ultrasound as a stethoscope” is quickly escalating from theory into reality. Some medical schools are now starting to provide to their pupils a portable equipment of ultrasound for use during clinical evaluations.

The ultrasound point-of-care is defined as brought to the patient, to side of the bed, and carried through in real time with images, that can be obtained almost immediately. It is used for several specialties in several procedures, including the peripheral vascular access, thoracentesis, paracentesis, arthrocentesis, regional anesthesia, incision and drainage of abscesses, location and removal of foreign bodies, lumbar puncture, biopsies, eye examination, among others. While examining the patient in trauma, among other applications, it has been used to evaluate a potentially fatal condition, the intracranial hypertension (IH).<sup>(1,2)</sup>

The gold standard method to diagnose the IH is done by inserting an intraventricular catheter that allows monitoring the intracranial pressure (ICP). However, it is an invasive, not immediate method and associated to complications, such as infection, bleeding and neurological dysfunction. Because of that, the clinical examination and the computerized cat scan of skull (CT) is used to suspect of IH and, after that, to carry through the invasive monitoring of the ICP for diagnostic purposes. In case doctors suspect of IH, by means of classic signals such as chronic headache, vomits, swelling of the optic nerve and the Cushing's response, characterized by a reflected increase of the arterial pressure, bradycardia and changes in the respiratory rhythm. The CT is the most used exam for patients with acute IH. Among the signs, there are: the presence of mass lesions, usually with mass effect (deviation of normal structures from their original position), midline shift, disappearance of the lateral ventricles and the third ventricle, dilated ventricular system, especially if followed by hypodensity around (transudate periventricular). However, for more than 80 years, it is recognized that the clinical examination is not a trustworthy parameter for evaluation of the IH. Using this single criterion, the IH is only detected in an advanced stage, when there is already intense brain damage or when the herniation and death may be inevitable. Concerning the CT, besides the fact that it might be unavailable in some services, it should not be performed in hemodynamically unstable patients, which is unfortunately common in patients' victim of trauma.<sup>(3-5)</sup>

The data showing the late appearance of IH clinical signs and the impossibility to transfer critically sick patients for the realization of neuroimaging methods, this study was created to evaluate the early detection of IH by the ultrasound of the optical nerve, aiming at a safe, reliable and practical diagnosis method for rapid therapeutic action.

## DISCUSSION

Intracranial Hypertension Trauma is an endemic disease of the modern society and it is currently the leading cause of death in Brazilian population of 1 to 40 years old. Only in Brazil, it is considered that, annually, 150,000 people die victims of traumas and 22 thousand out of this number are children and adolescents.

Eighty five percent of those with serious trauma had associated traumatic brain injury (TBI) and this injury corresponds to the absolute majority of deaths.<sup>(6,7)</sup>

One of the consequences of the TBI is the development of IH, defined in adults as IPC above 20 mmHg that persists for more than 20 minutes.<sup>(8)</sup> The intracranial pressure is the one found inside the braincase, with reference to the atmospheric pressure. It has a physiological variation from 5 to 15 mmHg and reflects the ratio between the content of the braincase (brain, cerebrospinal fluid and blood) and the volume of the skull, which can be considered constant (Monroe-Kellie Doctrine). Changing in the volume of these contents can lead to an IH and this, as it causes the reduction of cerebral perfusion pressure limiting or preventing the flow of blood and/or the herniations of brain structures, can cause neuronal death and proceed to death. Several authors associate the IH to a worse neurological outcome or to the greater mortality. The approach of patients is aimed at avoiding, identifying and correcting these factors in order to ensure an adequate supply of oxygen to the brain tissue. Immediate care for the correct diagnosis and stabilization of the patient is essential so as to avoid its disastrous consequences.<sup>(9,10)</sup>

Anatomy of the optic nerve. The optic canal, located in the minor wing of the sphenoid bone, receives the optic nerve (cranial pair II) coming from the intraorbital region, bringing retinal inputs. This nerve is surrounded by a meningeal sheath consisting of dura mater (pachymeninge), arachnoid and pia mater (both leptomeninges). The CSF content is present throughout the subarachnoid space and reflects the ICP. Due to the anatomical ratio of the complex of the optic nerve with all the subarachnoid cerebral space, an increase of the ICP results in the distension of the sheath and, therefore, an increase in its thickness, as well as the optic nerve sheath diameter (ONSD) directly translates the ICP.<sup>(11,12)</sup>

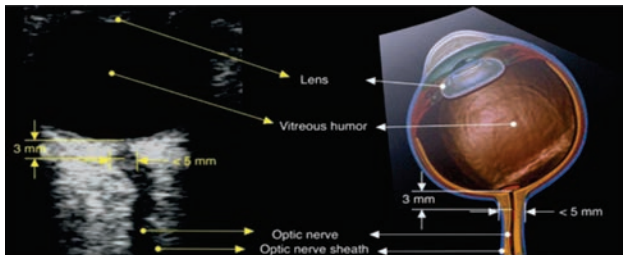
Ocular ultrasound and evaluation of ONSD. The use of ocular ultrasound was first reported in 1965 and currently proposes the quantification of ONSD as a non-invasive measure to detect IH. A high-frequency linear transducer (7-10MHz) is used and the ultrasound is set up to view structures up to 5 -6cm deep. The transducer is placed over the closed eyelid after generous application of gel,<sup>(13)</sup> (Figure 1).<sup>(14)</sup>



Source: Rajajee V, Vanaman M, Fletcher JJ, Jacobs TL. Optic nerve ultrasound for the detection of raised intracranial pressure. *Neurocrit Care*. 2011; 15(3):506-15.<sup>(14)</sup>

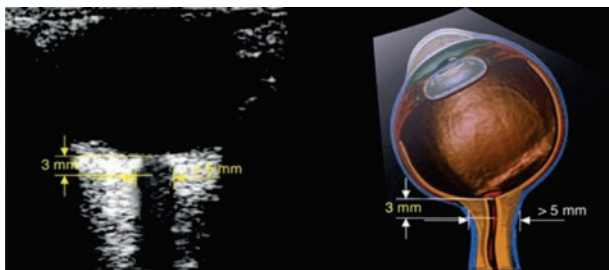
**Figure 1:** Optical ultrasound technique. The bougie is placed on the upper and lateral margin of the orbit, directed slightly to the inferior and medially, with the eyes closed.

The optic nerve is identified as a hypoechoic structure passing through, along a regular course behind the eyeball. For measurement, a vertical line is drawn from the junction between the optic nerve and the eyeball. This line serves only as a reference and its length should be 3mm. Once the length of 3mm is established, a horizontal line is drawn through the nerve. This second line provides the measurement of the optic nerve sheath in mm. (Figures 2 and 3).<sup>(15)</sup>



Source: Ochoa-Pérez L, Cardozo-Ocampo A. Aplicaciones de la ultrasonografía en el sistema nervioso central para Neuroanestesia y cuidado neurocrítico. *Rev Colomb Anestesiol.* 2015; 43(4):314-20.<sup>(15)</sup>

**Figure 2:** View of the sheath of the optic nerve. Normal diameter



Source: Ochoa-Pérez L, Cardozo-Ocampo A. Aplicaciones de la ultrasonografía en el sistema nervioso central para Neuroanestesia y cuidado neurocrítico. *Rev Colomb Anestesiol.* 2015; 43(4):314-20.<sup>(15)</sup>

**Figure 3:** View of the sheath of the optic nerve. Increased diameter.

## EVALUATION OF STUDIES

Several studies have assessed the ratio between IH and ONSD.

Julie et al. concluded, by means of a systematic review, that the ONSD is associated to an increase in ICP. The sensitivity of the study was 90% (95% IC 0.80-0.95,  $p = 0.09$ ), and the specificity was 85% (95% IC 0.73-0.93,  $p = 0.13$ ).<sup>(16)</sup>

Inessa et al. found out that for ICP greater than or equal to 20 mmHg, the ONSD provides readings with a cut-off value greater than or equal to 5.5 mm and which increase proportionally to the increase in ICP, contributing not only to the diagnosis, but quantitatively assessing its severity<sup>(17)</sup>

Komut et al., included in a control study case of 100 patients with suspected nontraumatic intracranial event. The patients were equally divided into 2 groups, including 50 patients in group I, who presented midline deviation in CT and in group II, 50 patients with normal CT. The cutoff value of the ONSD for detecting the midline change, associated with an increase in ICP, was determined as 5.3 mm. The ONSD values of groups I and II were  $5.4 \pm 1.1$  and  $4.1 \pm 0.5$  mm, respectively, concluding that the ONSD was higher in the group of patients with CT lesion, ( $P < 0.05$ ).<sup>(18)</sup>

In a comparison with an invasive ICP monitoring, Frumin et al, in a cross-sectional observational study, conducted a study with the purpose of correlating the ONSD with the previously existing IH and confirmed by invasive monitoring. A sonographer/physician, certified, performed an ultrasound on 27 patients with indication of invasive ICP monitoring, all ultrasound were performed within 24 hours after the placement of the external ventricular device. Six of these patients (22%) presented an ICP greater than 20 mmHg evidenced by the device. The sonographer was blinded to the ICP value recorded by the invasive monitor at the time of verification. A mean ONSD value of  $\geq 5.2$  mm was considered as positive for ICP > 20 mmHg. The Rank Spearman correlation coefficient on ONSD and ICP was 0.408 ( $p = 0.03$ ), showing a moderate positive correlation. A ROC curve was created to determine the ideal cutoff value to distinguish an ICP greater than 20 mmHg. The area under the characteristic curve of the receiving operator was 0.8712 (95% confidence interval [CI] = 0.67 to 0.96). It was concluded that the ONSD  $\geq 5.2$  mm was a good predictor of the ICP > 20 mmHg with a sensitivity of 83.3% (95% CI = 35.9% to 99.6%) and specificity of 100% (95% CI = 84.6% to 100%).<sup>(19)</sup>

In order to evaluate the different types of ultrasounds, Johnson et al, measured the ONSD three times, with two machines and five different models. A conventional ultrasound (Vscan, GE Healthcare) and a standard portable ultrasound (M-Turbo, SonoSite). The data were analyzed by the Bland-Altman methods and the intra-class correlation coefficient (ICC). The ICC between raters for SonoSite was 0.878, and for the Vscan it was 0.826. The agreement between ICC machines was 0.752. The analysis of the Bland-Altman agreement between the two ultrasound methods showed a uniform distribution over the entire range of sheath sizes, concluding that the precise measurement of its diameter may also be possible by using portable ultrasound devices, despite its small screen size, lower resolution and lower-wave frequencies.<sup>(20)</sup>

Hizir et al. carried out a case-control study in an intensive care unit evaluating the ONSD in forty-five patients. Nineteen patients were the group in which there was displacement of the midline to the cranial tomography and twenty-six patients were the control group, with no intracranial alterations. The Spearman difference coefficient correlation of the ONSD and the midline change was 0.761 ( $p < 0.0005$ ), demonstrating a significantly positive correlation between patients with midline change and the control group. Despite the small number and the selection bias, this study suggests that the ultrasound may be useful in the diagnosis of intracranial midline deviation by measuring the ONSD.<sup>(21)</sup>

It is well known of the lack of preparation of intensivists and emergency physicians in the use of the point-of-care ultrasound at the bedside. This is a still new technique that requires a learning curve, since the ultrasound is an examination which depends on the skill of the operator. On this issue, Zeiler et al., carried out a study in which a single operator measured the ONSD in 120 healthy volunteers for 6 months, performing 4 measurements on each volunteer in different periods and assuming in their study that the 4 measurements made should be the same. It was concluded that there was no difference in the total of mean values [ $3.69$  vs  $3.68$  mm ( $p = 0.884$ )] or in the variance between the subjects [ $14.49$  vs  $11.92$  ( $p = 0.54$ )], above or below these cut-off points, suggesting a finite, brief, and significant learning curve associated with the ONSD measurements.<sup>(22)</sup>

Reference value A disadvantage of the method is still the fact that there is no exact reference on the ONSD value to diagnose the IH. However, several authors in their studies, have

shown that a  $\geq 5$  mm value is clearly related to a value of the ICP  $> 20$  mmHg. The following table summarizes the studies with their reference, sensitivity and specificity values. It can't, however, compare the studies because they show different designs and sample numbers.

Studies	Diameter of the optic nerve em Mm	Sensitivity (%)	Specificity (%)
Goel et al. <sup>(23)</sup>	5 mm	98.6	92.8
Kimberly et al. <sup>(24)</sup>	5 mm	88	93
Major et al. <sup>(25)</sup>	5 mm	100	86
Aduayi et al. <sup>(12)</sup>	5.2 mm	81.2	100
Frumin et al. <sup>(19)</sup>	5.2 mm	83.3	100
Komut et al. <sup>(18)</sup>	5.3 mm	70	74
Lee et al. <sup>(26)</sup>	5.5 mm	98.77	85.19
Padayachy et al. <sup>(27)</sup> children < 1 year	5.16 mm	93.2	74
Padayachy et al. <sup>(27)</sup> children < 1 year	5.75mm	93.2	74

## CONCLUSION

With the limitations concerning the unpreparedness of the doctors in the use of the ultrasound and the lack of an accurate value of reference as a way to measure the IH diagnosis through the ONSD, we came to the conclusion that more preparedness from the professionals and more prospective and multicenter studies destined to reach a reference standard value are necessary. However, in this new way to evaluate the IH, there is an examination of low cost, with good accuracy, fast, not invasive, recommended for the non specialist doctor, without ionizing radiation and performed by the bedside, being considered therefore as a promising and extremely efficient examination to evaluate the critical patients.

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