

Relationship between the measurement by tomography and ultrasound of the diameter of the optic nerve sheath as a non-invasive estimator of intracranial pressure

Relación entre la medición por tomografía y ultrasonido del diámetro de la vaina del nervio óptico como estimador no invasivo de la presión intracraneal

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Abstract

Objective: To compare the ONSD measured by ultrasound and tomography in patients with a diagnosis of intracranial hypertension. **Method:** Prospective, transversal, observational, analytical study. 105 patients were included, divided into two groups: healthy (control group) and patients presenting clinical data of intracranial hypertension (study group). ONSD was measured by ultrasound and tomography. The Kruskal-Wallis test was used to compare the ONSD between the patients, and the Spearman test was used to assess the correlation between USG and CT. A value of $p < 0.05$ was considered statistically significant. **Results:** Of the 105 patients, 58.1% were men and 41.9% women. The study group included 14 patients with TBI, CVD, intracranial neoplasia, or neuroinfection. The highest median of ONSD by Ultrasound was in the CVD group, followed by TBI, neoplasia and neuroinfection and the lowest was in the control group (7.5, 7.0, 6.8, 6.8 and 5.2 mm respectively); these differences being statistically significant ($p < 0.001$). In the correlation analysis between Ultrasound and CT, a good statistically significant positive correlation was found ($\rho = 0.893$, $p < 0.001$). **Conclusions:** The ultrasound evaluation of ONSD has proven to be a reliable test for the diagnosis and non-invasive monitoring of intracranial hypertension.

Keywords: Neuromonitoring. Optic nerve. Intracranial pressure.

Resumen

Objetivo: Comparar la ONSD medida por ecografía y tomografía en pacientes con diagnóstico de hipertensión intracraneal. **Método:** Estudio prospectivo, transversal, observacional, analítico. Se incluyeron 105 pacientes, divididos en dos grupos: sanos (grupo control) y pacientes que presentaban datos clínicos de hipertensión intracraneal (grupo estudio). ONSD se midió por ultrasonido y tomografía. Se utilizó la prueba de Kruskal-Wallis para comparar la ONSD entre los pacientes y la prueba de Spearman para evaluar la correlación entre la USG y la TC. Se consideró estadísticamente significativo un valor de $p < 0.05$. **Resultados:** De los 105 pacientes, el 58.1% eran hombres y el 41.9% mujeres. El grupo de estudio incluyó a 14 pacientes con TBI, ECV, neoplasia intracraneal o neuroinfección. La mediana más alta de ONSD por Ultrasonido fue en el grupo ECV, seguida de TCE, neoplasia y neuroinfección y la más baja fue en el grupo control (7.5, 7.0, 6.8, 6.8 y 5.2 mm respectivamente); siendo estas diferencias estadísticamente significativas ($p < 0.001$). En el análisis de correlación entre Ultrasonido y TC se encontró una buena correlación positiva estadísticamente significativa ($\rho = 0.893$, $p < 0.001$). **Conclusiones:** La evaluación ecográfica de la ONSD ha demostrado ser una prueba fiable para el diagnóstico y seguimiento no invasivo de la hipertensión intracraneal.

Palabras clave: Neuromonitorización. Nervio óptico. Presión intracraneal.

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Introduction

The use of ultrasound has become an integral part of critical care in recent years. Provides rapid, repeatable, multisystem assessment to guide diagnosis and treatment of patients, without requiring patients to be transported outside of their clinical setting for imaging^{1,2}.

Compared to conventional neuroimaging methods (such as computed tomography [CT] or magnetic resonance imaging), ultrasonography (USG) also offers a continuous neurological monitoring system^{3,4}. The combined use of multiple tools or “multimodal monitoring” is common in critically ill patient care areas. Its application is based on complementing the neurological examination and evaluating the progression of the disease in patients whose clinical characteristics of the condition are confused by the effects of sedation, analgesia or neuromuscular blockade, among others, and in comatose patients (eg., severe cerebral edema, seizures, and cerebral ischemia) in which neurologic responses approach minimal and become insensitive to clinical assessment⁵.

Elevated intracranial pressure (ICP), or intracranial hypertension, is a common problem in patients after brain injury. Not only is it an acute neurological problem, but it also contributes to poor outcomes, as it is directly related to increased mortality, or it can lead to permanent neurological sequelae^{6,7}. Increased ICP may arise from traumatic injury, hemorrhage, occupational (neoplastic) injury, impaired cerebrospinal fluid circulation, obstruction of the greater venous sinuses, or occasionally be idiopathic. Intracranial hypertension virtually reduces the caliber of the cerebral vasculature and therefore reduces blood flow and cerebral perfusion pressures^{8,9}.

The primary goal of ICP monitoring is to guide therapies that limit intracranial hypertension and optimize cerebral perfusion⁹. The current reference method for monitoring changes in ICP is the intraventricular or intraparenchymal pressure transducer, placed in the brain parenchyma. However, many patients may not receive this monitoring due to the associated risks, such as infections and bleeding, as well as the limited availability of the resource^{8,9}.

As a result, efforts have been made to develop non-invasive, widely available, and easy-to-use methods to monitor changes in ICP in brain-injured patients^{9,10}.

The use of USG in the field of neurology was first described by Karl Dussik in 1942, at the University of

Vienna, for the diagnosis of brain tumors. Despite the sonically impenetrable nature of bone, there are two areas in the (adult) head to obtain an acoustic window: the ocular window and the transcranial windows on the perimeter of the skull¹¹.

Currently it can include, among many other applications, the identification of an increase in ICP through images of the diameter of the optic nerve sheath (DVNO). In a recent meta-analysis, Robba et al.¹² concluded that DVNO may be useful for ICP monitoring, as an indicator of intracranial hypertension, when standard invasive monitors are not available or indicated¹².

The optic nerve is surrounded by the meningeal layers, and cerebrospinal fluid flows freely between the intracranial and intraorbital subarachnoid spaces, which experience the same pressure changes. In 1968, Hayreh established the presence of a constant communication between the subarachnoid space of the optic nerve sheath and the intracranial cavity^{13,14}. The optic nerve is wrapped in this sheath that contains cerebrospinal fluid, so in conditions of increased ICP the diameter of the sheath increases¹³. Therefore, the width (or diameter) of the optic nerve sheath as seen by USG is useful as a non-invasive means of assessing ICP changes, primarily intracranial hypertension¹⁴.

USG measurements of greater than 5.0 mm DVNO have been shown to correlate with increased ICP, and in a prospective trial showed 100% sensitivity and 63% specificity for identifying elevated ICP through this method¹⁵.

The DVNO has utility for ICP measurement in intracranial hemorrhage and ischemic stroke, meningitis and encephalitis, and idiopathic intracranial hypertension^{16,17}.

The optic nerve measurement technique for estimating ICP, based on the concept that the optic nerve is an extension of the central nervous system, was first described by Helmke and Hansen in 1997¹⁸.

A “normal” DVNO on ultrasound is considered < 5.0 mm for adults; values above the indicated are considered abnormal^{2,11}. Comparing linear regression models, DVNO is a much stronger predictor of intracranial hypertension compared with other CT features^{18,19}.

USG measurement of DVNO is proposed as a non-invasive, fast, and accessible tool to identify intracranial hypertension. The main objective of this study was to compare and correlate the DVNO obtained by CT and USG in patients with a clinical diagnosis of intracranial hypertension, with some associated central nervous system lesion.

Method

A prospective, cross-sectional, observational and analytical study was carried out with 105 adult patients (over 18 years of age) divided into two groups: healthy (control group) and patients with some lesion of the central nervous system who presented clinical data of intracranial hypertension (group study).

The study group included 14 patients with clinical data of intracranial hypertension and with any of the following lesions: head trauma, cerebral vascular event, some type of intracranial neoplasia or diagnosis of neuroinfection. In addition to the lesion of the central nervous system, the CT evaluated the presence of displacement of the midline, blurring of the fissures, or severe cerebral edema suggestive of intracranial hypertension. The clinical data considered were hypertension, bradycardia and alterations in the respiratory pattern (classic triad), in addition to alterations in consciousness (drowsiness, stupor or coma), persistent progressive headache, expulsive vomiting (projectile), papilledema, vision blurred or tinnitus; those patients with four or more of these symptoms were included.

DVNO was measured by USG in the control group, and by USG and CT in the study group. To carry out the USG measurements, a Philips brand equipment, model Affiniti 70, with a 7.5 MHz linear transducer, was used in two-dimensional mode at 3 mm behind the eyeball. The CT evaluation was carried out with a Siemens brand equipment, Somatom Sensation 64. The same equipment was always used in all patients.

A descriptive statistical analysis of the information was performed. Qualitative variables were expressed by simple frequencies and percentages, while numerical variables (age, DVNO) were expressed with median and interquartile range (difference between 75th and 25th percentiles), due to their non-normal distribution.

The patients were grouped into healthy and sick, and to compare the distribution of the variables between these groups, the χ^2 and U of Mann-Whitney tests were used. The Kruskal-Wallis test was used to compare the DVNO among the patients (healthy, head trauma, intracranial neoplasia, cerebrovascular event, and neuroinfection). Finally, to evaluate the correlation between DVNO by USG and CT, a scatter plot of points was constructed and Spearman's test was used. A value of $p < 0.05$ was considered as statistically significant. This study was carried out under the ethical conditions of the unit.

Table 1. General characteristics of the patients

Characteristics	n = 105
Sex	
Male	61 (58.1%)
Female	44 (41.9%)
Age, years	30 $\pm$ 4
20-39	96 (91.4%)
40-59	7 (6.7%)
60 and over	2 (1.9%)
Patient groups	
Healthy	91 (86.7%)
Head trauma	8 (7.6%)
Intracranial neoplasm	3 (2.9%)
Neuroinfection	2 (1.9%)
Cerebral vascular event	1 (1%)

Data are shown as number (%) or median $\pm$ interquartile range.

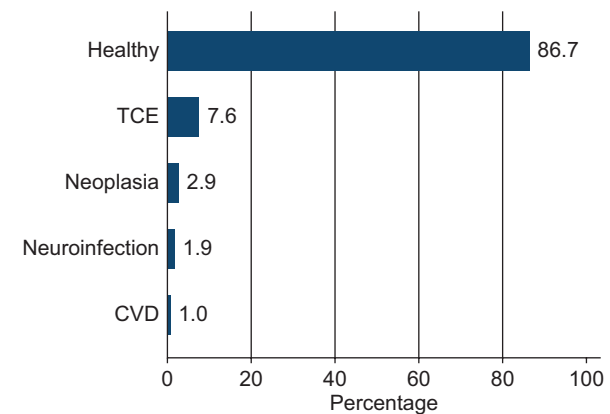


Figure 1. Graph showing the distribution of patients. CVD: cerebral vascular event; TCE: traumatic brain injury.

Results

105 subjects were included in the study, of which 58.1% were men and 41.9% were women. The median age was 30 years and 91.4% were between 20 and 39 years (Table 1).

91 patients (86.7%) belonged to the control group (healthy) and 14 patients were included in the study group: eight with head trauma, three with intracranial neoplasia, two with neuroinfection, and one with a cerebral vascular event (Fig. 1).

When comparing the healthy and sick subjects, it was found that the median age was higher in the sick group (45 vs. 30 years; $p < 0.001$), with differences in the distribution by age groups. In the distribution by sex, no differences were found between the groups (Table 2).

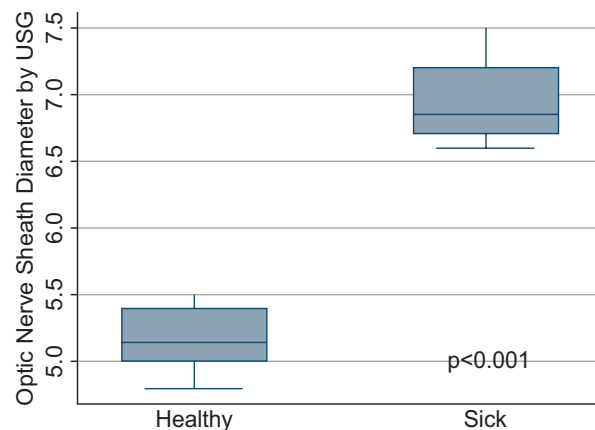
Table 2. Characteristics in sick and healthy subjects

Characteristics	Sick	Healthy	Both groups	p*
n	14	91	105	
Sex				
Male	7 (50%)	54 (59.3%)	61 (58.1%)	0.510
Female	7 (50%)	37 (40.7%)	44 (41.9%)	
Age, years	45 ± 16	30 ± 4	30 ± 4	< 0.001
20-39	6 (42.9%)	90 (98.9%)	96 (91.4%)	
40-59	6 (42.9%)	1 (1.1%)	7 (6.7%)	
60 and over	2 (14.3%)	0 (0%)	2 (1.9%)	< 0.001
DVNO by USG, mm	6.9 ± 0.5	4.2 ± 0.4	5.2 ± 0.5	
DVNO by TC, mm	6.8 ± 0.4	ND	6.8 ± 0.4	ND

Data are shown as number (%) or median ± interquartile range.

*p value using χ^2 or Mann-Whitney U test.

DVNO: diameter of the optic nerve sheath; NA: not available; CT: computed tomography; USG: ultrasonography.

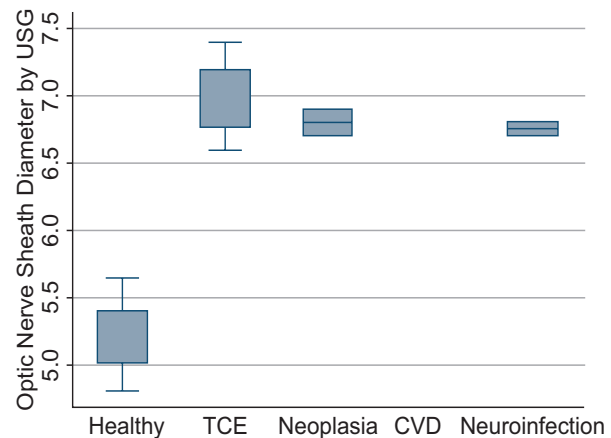
**Figure 2. Measured diameter of the optic nerve sheath by USG in healthy and diseased patients. USG: ultrasonography.**

The median DVNO by USG was notably higher in the group of patients (6.9 mm) than in the healthy group (4.2 mm; $p < 0.001$) (Fig. 2).

The highest median DVNO by USG was in the group with cerebrovascular event, followed by patients with head trauma, neoplasia, and neuroinfection, and the lowest was in the control group (7.5, 7.0, 6.8, 6.8, and 5.2 mm, respectively), these differences being statistically significant ($p < 0.001$) (Fig. 3).

In addition to the USG measurement, a head CT study was performed on the study group and the DVNO was also measured by this method (Table 3).

Regarding the measurements of DVNO by CT performed in sick patients, these were very similar between the groups ($p = 0.406$) (Fig. 4).

**Figure 3. Optic nerve sheath diameter measured by USG according to the type of patient. CVD: cerebral vascular event; TCE: traumatic brain injury; USG: ultrasonography.****Table 3. Optic nerve sheath diameter according to patient group**

Groups	DVNO by USG	DVNO by CT
Healthy	5.2 ± 0.4	ND
Head trauma	7.0 ± 0.5	7.1 ± 0.5
Intracranial neoplasm	6.8 ± 0.2	6.7 ± 0.1
Neuroinfection	6.8 ± 0.1	6.7 ± 0.2
Cerebral vascular event	7.5 ± 0	6.9 ± 0
p*	< 0.001	0.406

Data are shown as number (%) or median ± interquartile range.

*p value using χ^2 or Mann-Whitney U test.

DVNO: diameter of the optic nerve sheath; NA: not available; CT: computed tomography; USG: ultrasonography.

In the correlation analysis between the DVNO by USG and CT in the study group, a good statistically significant positive correlation was found ($\rho: 0.893$; $p < 0.001$) (Fig. 5).

Discussion

Images are essential in the diagnosis and management of patients with neurological disease, perhaps more than in any other area of medicine^{18,19}.

Changes in DVNO and USG measurement appear to be more linearly related to increased ICP; this relationship and the high sensitivity demonstrated provide a useful tool to rule out intracranial hypertension as a cause of altered mental status in a critically ill patient¹⁹.

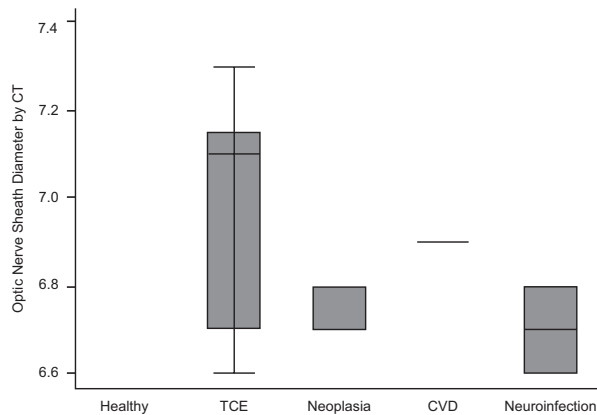


Figure 4. Optic nerve sheath diameter measured by CT according to the type of patient. CVD: cerebral vascular event; CT: tomography; TCE: traumatic brain injury.

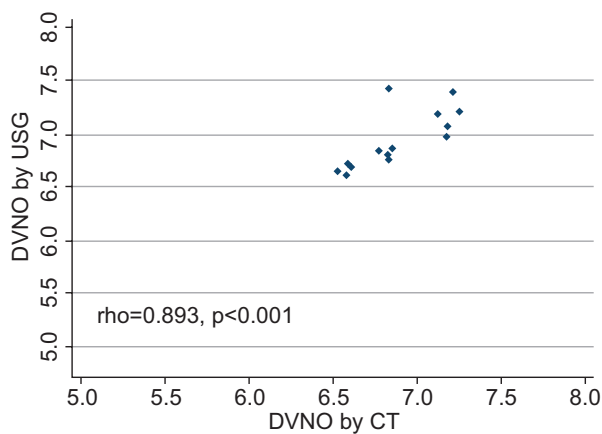


Figure 5. Correlation between optic nerve sheath diameter (ONDV) by ultrasonography (USG) and computed tomography (CT) in diseased patients. DVNO: diameter of the optic nerve sheath; CT: tomography; USG: ultrasonography.

It is estimated that the learning curve for physicians experienced in the use of USG may include as few as 10 patients to perform the study accurately, while physicians unfamiliar with USG may need about 25 scans to obtain the accuracy. necessary dexterity and accurately assess the DVNO²⁰.

There are multiple causes of elevated ICP, which is why it was considered to include different pathologies that affect the central nervous system in this study. The purpose of this work was to evaluate patients with clinical data of intracranial hypertension, regardless of the triggering factor, but who, according to the results, could find a direct relationship with the specific cause.

The control group was useful for acquiring greater skill in USG evaluation of the optic nerve and its

measurement in healthy subjects. The sample obtained from the study group was uniform in terms of the sex of the patients evaluated (50% men and 50% women), and more than 75% were in an age range of 28 to 49 years, with a mean of 45.4 years and a median of 45, showing a normal or similar distribution in the group of patients with data of intracranial hypertension.

It was observed that 100% of the patients with a clinical diagnosis of intracranial hypertension and an associated neurological lesion presented an increase in DVNO, measured with USG and corroborated by CT, and according to our results there is a strong positive correlation between both methods, which was considered statistically significant ($p < 0.001$).

The present study demonstrates that the measurement of DVNO by USG is a non-invasive, low-cost, easy-to-operate method that can be performed at the patient's bedside, and that it should be considered in the initial approach to neurocritical patients and for close monitoring of its evolution.

Conclusions

Elevated ICP is a common condition with poor clinical outcomes and high mortality rates. The main objective of ICP monitoring is to guide therapies that limit intracranial hypertension, optimize cerebral perfusion, and implement and evaluate the response to the interventions performed.

Currently, focused ultrasound is used by various specialties in various monitoring, diagnostic, and intervention situations. The DVNO measurements are correlated with non-invasive and invasive ICP measurements and with the tomographic findings of the different brain lesions that may be the cause of elevated ICP. USG evaluation of the DVNO has proven to be a reliable test for the non-invasive diagnosis of elevated ICP in neurocritical patients.

It must be recognized that no monitor will ultimately change the outcome. Instead, how that information is integrated and interpreted in decision-making is what will influence the outcome of the patient.

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Conflicts of interest

The authors declare not to have any conflicts of interest.

Ethical disclosures

Protection of people and animals. The authors declare that no experiments were carried out on humans or animals for this research.

Data confidentiality. The authors declare that no patient data appears in this article.

Right to privacy and informed consent. The authors declare that no patient data appears in this article.

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