Intra- and interobserver reliability of transorbital sonographic assessment of the optic nerve sheath diameter and optic nerve diameter in healthy adults

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Abstract

Purpose Transorbital optic nerve sonography (TOS) can measure the optic nerve inclusive the sheath diameter (ONSD) and the optic nerve diameter (OND), which are useful parameters in the diagnosis of several neurological disorders. Data on the reproducibility of TOS are, however, required to use B-mode sonography for clinical purposes. The aim of this study was to assess intra- and interobserver reliability of ultrasound-based evaluations of both OND and ONSD in healthy subjects.

Methods Using a 4–11-MHz linear array transducer, the OND and ONSD of 20 healthy subjects were independently measured by two expert investigators.

Results Depicting the optic nerve and its sheath was possible in all subjects. The intra- and interobserver reliability was high for both ONSD and OND measurements. Intraobserver agreement, analyzed with Cronbach's Alpha, was higher for ONSD (range: 0.69–0.72) than for OND measurements (range: 0.55–0.65). No differences in interobserver reliability between ONSD and OND measurements were found ($p = 0.83$ for right and 0.47 for left eye).

Conclusions Transorbital B-mode sonography is a feasible method to assess both ONSD and OND with a high intra- and interobserver reliability. Technical difficulties in differentiating the optic nerve from its sheaths may explain the lower intraobserver agreement for OND than that for ONSD measurements.

Keywords Interobserver reliability · Intraobserver reliability · Optic nerve diameter · Optic nerve sheath diameter · Transorbital sonography

Sommario

Obiettivo La sonografia del nervo ottico per via transcranica (TOS) è in grado di misurare il diametro del nervo ottico inclusi i suoi rivestimenti (ONSD) o il diametro del solo nervo ottico (OND), parametri utili nella diagnostica di molte patologie neurologiche. È necessario tuttavia disporre di dati sulla riproducibilità di tale metodica, ottenuta in sonografia B-mode, per poterla applicare clinicamente. Obiettivo di questo studio è stato quello di determinare il grado di riproducibilità intra- e inter-osservatore nella determinazione di questi due parametri in soggetti sani.

Metodi Due esaminatori hanno determinato in maniera indipendente valori di ONSD ed OND in 20 soggetti sani utilizzando una sonda ecografica a 4–11 MHz.

Risultati In tutti i soggetti è stato possibile visualizzare il nervo ottico e i suoi rivestimenti. Sono stati ottenuti elevati valori di riproducibilità intra- e inter-osservatore nella determinazione dell'ONSD e dell'OND. La riproducibilità intra-osservatore, analizzata con il metodo del Cronbach's Alpha, era maggiore per l'ONSD (range: 0.69–0.72) che per l'OND (range 0.55–0.65). Non sono state riscontrate differenze nella riproducibilità inter-osservatore tra ONSD ed OND ($p = 0.83$ per l'occhio destro e 0.47 per quello sinistro).

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Conclusioni La TOS è un metodo in grado di ottenere i valori di ONSD ed OND con elevato grado di riproducibilità intra- ed inter-osservatore. Difficoltà tecniche nel distinguere il nervo ottico dai suoi rivestimenti possono spiegare il minor grado di riproducibilità intra-osservatore per l'OND rispetto all'ONSD.

Introduction

Transorbital optic nerve sonography (TOS) can be used to measure both the optic nerve sheath diameter (ONSD) and the optic nerve diameter (OND). The former parameter can be used to identify intracranial hypertension due to different causes, since an increased intracranial pressure of different aetiologies leads to enlargement of the ONSD [1, 2]. Optic nerve diameter can be useful to detect the presence of optic nerve atrophy in patients with multiple sclerosis [3, 4]. It was found to have a positive correlation with brain demyelinating lesions (plaque load) in multiple sclerosis [5] or with severity of traumatic brain injury on computed tomography head scan [6]. In the literature, there are conflicting data regarding the relationship between the OND and the intracranial pressure levels, with one study reporting no correlation [7], and others supporting a positive correlation [8, 9].

Data on the reproducibility of this method are, however, required to use B-mode sonography for clinical purposes. In a previous study, we already established normal values and assessed the intra- and interobserver reliability of ultrasound-based evaluation of the ONSD [10]. However, to date, no study has been conducted to assess the reproducibility of TOS assessment of OND. We therefore aimed to evaluate intra- and interobserver reliability of ultrasound-based evaluation of both OND and ONSD.

Materials

Study subjects

Study subjects were recruited in the Department of Neurology of the University A. Avogadro, Novara, Italy. The study group consisted of students, department staff, and family members of patients. Written informed consent was obtained from all persons before entering the study. All subjects were aged 18 years or older and had no history of any neurological disease. The study was approved by the local ethics committee (Novara No. 96/2013). All procedures followed were in accordance with the ethical standards of the responsible committee on

human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. All patients provided written informed consent to enrolment in the study and to the inclusion in this article of information that could potentially lead to their identification.

Transorbital sonography

Transorbital sonography (TOS) was performed in B-mode using a Toshiba Aplio XG (Toshiba Medical System, Aplio Nasu, Japan) equipped by a 4–11-MHz 5 S1 Linear Probe. Two expert sonographers (PL and LC), trained in TOS before starting the study, carried out the examinations. The investigators examined independently both eyes in each subject, without being aware of each other's findings. Each eye was examined three times, and measurements were made in both eyes for every individual.

Subjects were examined in supine position with the head and the upper part of the body elevated to 20–30° to avoid any pressure on the eye and were asked to keep their eyes in a neutral position, trying to suppress eye movements. The mechanical index was reduced to 0.2 for safety reasons [11]. The probe was placed on the temporal part of the closed upper eyelid and a thick layer of ultrasound gel was applied. The anterior part of the optic nerve was depicted in an axial plane with the papilla and the optic nerve shown longitudinally, Fig. 1). The ONSD and OND were assessed

Fig. 1 Ultrasound examinations of the eye carried out in B-mode. The optic nerve diameter (OND) and optic nerve sheath diameter (ONSD) were measured 3 mm behind the papilla (a), using an electronic caliper and an axis perpendicular to the optic nerve. The OND was measured as the distance inside pia mater (d), and the ONSD as the distance inside dura mater (c–b)

3 mm behind the papilla. The distance between the external borders of the hyperechogenic area surrounding the optic nerve was quantified to measure the ONSD, by marking the internal borders of this formation.

Statistics

Values are expressed as mean $\pm$ 2 standard deviation (SD). The intraobserver reliability was analyzed using Cronbach's Alpha, which is a model of internal consistency, based on average interim correlation. A value of 1 would indicate maximum consistency of values. In order to assess the agreement between the measurements of the two investigators (interobserver reliability), Bland–Altman analysis was used. All statistical analyses were performed using Excel 2007 implemented with Real Statistics Resource Pack (available at: <http://www.real-statistics.com/>) and SPSS for Windows software Release 16.0 (SPSS Inc., Chicago, IL, USA).

Results

The ONSD was measured in 20 individuals aged from 23 to 82 years (mean 46.3 ± 16.4 years). Thirteen participants were female (65 %), and seven were male (35 %). Evaluation of the ONSD and OND was possible in all subjects. Signs of papilloedema were not found. Mean ONSD assessed 3 mm behind the entry of the nerve into the bulb was 5.95 ± 0.68 mm, with a range of 4.5–7.7 mm. Mean OND was 3.08 ± 0.38 mm, with a range of 2.1–3.8 mm. Additional descriptive statistics are presented in Table 1.

Overall, intraobserver agreement was higher for measurements of ONSD (Cronbach's Alpha: 0.69 for the right and 0.69 for the left bulb—examinator 1; 0.72 for the right and 0.72 for the left bulb—examinator 2) than for OND (Cronbach's Alpha: 0.65 for the right and 0.55 for the left

bulb—examinator 1; 0.63 for the right and 0.64 for the left bulb—examinator 2).

Regarding interrater reliability, Bland–Altman analysis yielded a mean difference of measurements of OND of 0.10 ± 0.30 mm for the right and 0.18 ± 0.37 mm for the left bulb. Limits of agreement (mean $\pm$ 2 SD) were 0.70 and -0.50 mm for the right and 0.93 and -0.56 mm for the left bulb (Fig. 2). Bland–Altman analysis yielded a mean difference of measurements of ONSD of 0.08 ± 0.28 mm for the right and 0.09 ± 0.40 mm for the left bulb. Limits of agreement (mean $\pm$ 2 SD) were 0.48 and -0.64 mm for the right and 0.71 and -0.90 mm for the left bulb (Fig. 3). No differences in interobserver reliability between ONSD and OND measurements were found ($p = 0.83$ for right and 0.47 for the left eye).

Discussion

The major finding of this study is that both ONSD and OND can be assessed with high intra- and interobserver reliability using transorbital B-mode sonography.

Overall, intraobserver agreement was higher for ONSD than for OND measurements, probably because of technical difficulties to differentiate in a very reliable and accurate way the optic nerve from its sheaths. Although investigators performed TOS independently from each other, they could not be blinded to their own results, and this may have affected the evaluation of intraobserver agreement.

Regarding the interobserver reliability, Bland–Altman plots elucidated a robust agreement of ONSD and OND gauging by different examiners. The mean differences were close to zero indicating no evidence of a systematic bias.

A previous study evaluated the interobserver reliability in OND and ONSD measurements tested by two radiologists on 23 magnetic resonance imaging (MRI) datasets,

Table 1 Optic nerve diameter (OND) and optic nerve sheath diameter (ONSD) (mm) in 20 Individuals

	Right bulb OND		Left bulb OND		Both bulbs OND
	Investigator 1	Investigator 2	Investigator 1	Investigator 2	Both investigators
Mean	3.01	3.11	3.00	3.19	3.08
Standard deviation	0.36	0.38	0.32	0.41	0.38
Median	3.00	3.20	3.00	3.20	3.10
ONSD					
	Investigator 1	Investigator 2	Investigator 1	Investigator 2	Both investigators
Mean	6.02	5.94	5.98	5.88	5.95
Standard deviation	0.63	0.64	0.68	0.78	0.68
Median	6.10	5.80	6.00	5.70	6.00

Fig. 2 To assess the agreement between the measurements of the two investigators for OND in the *right* (a) and the *left* (b) bulb, Bland–Altman plots were used. *Thin line* depicts the mean of difference; *thick lines* denote limits of agreements (mean difference $\pm$ 2 SD)

Fig. 3 Bland–Altman plots of interobserver agreement for ONSD measurements in the *right* (a) and the *left* (b) bulb. *Thin line* depicts the mean of difference; *thick lines* denote limits of agreements (mean difference $\pm$ 2 SD)

corresponding to 22 individuals (12 healthy subjects and 10 patients with traumatic brain injury) [8]. In this study, the mean difference between observers for ONSD was smaller (0.11 mm) than that for OND (0.30 mm), and the mean standard deviation for OND was higher (0.25 mm) than that for ONSD (0.17) ($p = 0.005$) [8]. Conversely, in our study, we found no differences in interobserver reliability between ONSD and OND measurements tested using TOS. Overall considered, these data suggest that, with regards to interobserver agreement, TOS might be more reliable than MRI for both ONSD and OND measurements. However, further studies directly comparing MRI and TOS in measuring ONSD and OND are required to evaluate the degree of reliability across these diagnostic techniques.

In conclusion, our study demonstrates that transorbital B-mode sonography is a reliable method to assess both ONSD and OND. The results of our study could be seen as a basis for future investigations on noninvasive TOS assessment of different neurological disorders.

Conflict of interest Piergiorgio Lochner, Lorenzo Coppo, Roberto Cantello, Raffaele Nardone, Andrea Naldi, Maurizio A. Leone, Francesco Brigo declare that they have no conflict of interest.

Human and animal studies The study described in this article does not contain studies with human or animal subjects performed by any of the authors.

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