Correlation of Visual Axis and Coronal Axis Measurements of the Optic Nerve Sheath Diameter

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Objective. There are several approaches to sonographic imaging and measurement of the optic nerve sheath diameter (ONSD). In this study, we sought to compare visual axis measurements of the optic nerve sheath (ONS) with traditional coronal axis measurements to assess for correlation. Methods. The ONS was visualized in 2 views on both eyes of healthy volunteers using an 8.5-MHz probe. Coronal axis views were obtained with the probe placed at the lateral canthus directed nasally posterior to the globe. Subsequent imaging was made along the midline visual axis. The diameter in this view was measured at several points posterior to the sclera (2, 3, 6, 9, 12, and 15 mm). Results. Twenty-seven subjects were enrolled (54 scans). There was a significant difference between ONSDs measured in each axis, with a coronal axis mean diameter of 3.4 mm and visual axis mean diameters at 2, 3, 6, 9, 12, and 15 mm of 4.28, 4.32, 5.15, 5.74, 6.39, and 7.42 mm, respectively (P < .05). The Pearson coefficient showed no correlation between coronal axis and visual axis measurements, with R values ranging from 0.51 to 0.69. There was a statistically significant increase in the ONSD as the nerve coursed posteriorly when measured in the visual axis. Conclusions. Visual axis measurements do not reliably correlate with coronal axis measurements. The consistently larger diameter measured in the visual axis as well as the gradually increasing diameter posteriorly suggests measurement of an artifactual shadow rather than the true ONS. Key words: measurement; optic nerve; optic nerve sheath; sonography.
It is unclear whether these different scanning techniques yield comparable results for measurements of the ONSD. In this study, we sought to compare ONSD measurements taken via visual axis versus coronal axis approaches to assess for correlation in healthy subjects.

**Materials and Methods**

Ophthalmic sonographic examinations were performed on healthy volunteers. Exclusion criteria for participation in the study included age younger than 18 years, a history of glaucoma, recent head or ocular trauma, and a history of a pseudotumor cerebri, hydrocephalus, or a ventriculoperitoneal shunt. Imaging was performed with an 8.5-MHz endocavitary probe on a MicroMaxx ultrasound machine (SonoSite, Inc, Bothell, WA). All images were recorded on thermal paper for later review.

Sonographic imaging was performed on both eyes of each subject, with ONSD measurements taken using 2 approaches. The first approach was visual axis imaging performed by placing the probe anteriorly over a closed eyelid with the indicator directed nasally. With the subject fixed in a primary gaze, the ultrasound beam was directed posteriorly, imaging the ON behind the globe (Figure 1). The second approach was coronal axis imaging performed with a vertical transverse scanning orientation with the probe placed temporally at the lateral canthus and the beam directed nasally. With the indicator cephalad, this technique provides a cross section of the ON just posterior to the globe (Figure 2). Instructing patients to direct their gaze temporally facilitated coronal axis views. Both visual axis and coronal axis views were obtained by the same sonographer for each subject. However, not all examinations were performed by the same sonographer, with equal distribution of examinations performed by 3 of the study authors (D.J.B., R.J.G., and A.M.).

Multiple ONSD measurements in the visual axis were performed on the recorded images with mechanical calipers. Measurements were recorded at 2, 3, 6, 9, 12, and 15 mm posterior to the globe when sufficient detail existed to make an accurate measurement. Coronal axis measurements were made from the superior limit of the nerve sheath to the inferior limit to eliminate the potential for falsely enlarged measurements due to oblique cuts through the nerve. The use of mechanical calipers allowed more precise measurements (0.1 mm) at predetermined locations along the course of the ON. To ensure blinding, a single investigator was responsible for adjusting the calipers without knowledge of the resulting measurement, while a second investigator recorded the value of the caliper measurement before resetting the caliper to 0. This process was repeated for all ONSD measurements, which were then corrected for scale and recorded on a computerized data sheet.

An a priori power calculation estimated a need for 28 sonograms to detect a 0.5-mm discrepancy between ONSD measurements taken in the two approaches ($\alpha = .05; \beta = .8$). Statistical analy-
sis of data used the Student $t$ test for differences in means and the Pearson coefficient for analysis of correlations of all measurements in the two approaches (P. Wessa, Free Statistics Software, Office for Research Development and Education, version 1.1.21, 2007; http://www.wessa.net). Approval for this study was obtained from the University of Massachusetts Institutional Review Board. Informed consent was obtained from all volunteers.

Results

Fifty-three ophthalmic sonographic examinations were performed on 27 volunteers. The examinations were performed by 1 of 3 sonographers experienced in ophthalmic sonography. The average age of the subjects was 36.6 years with a male-to-female predominance of 3:1.

The mean values for the ONSD measured along the visual axis at 2, 3, 6, 9, 12, and 15 mm are detailed in Table 1. The sonographic measurements made along the visual axis did not correlate with the measurements obtained along the coronal axis. The mean ONSD using a coronal approach (3.4 mm; 95% confidence interval, 3.18–3.61 mm) was statistically smaller than any visual axis measurements (4.28–7.42 mm; $P < .05$ for all comparisons). The Pearson coefficient showed poor correlation between individual coronal axis and visual axis measurements at any point. $R$ values for 2, 3, 6, 9, 12 and 15 mm were 0.69, 0.61, 0.63, 0.68, 0.59, and 0.51, respectively. A representative scatterplot for the coronal axis versus visual axis (measured at 3 mm posterior to the sclera) is shown in Figure 3.

Several data points for visual axis measurements were lost secondary to image quality limitations making the nerve borders indistinct and unmeasurable. The number and degree of sonographic artifacts were less with coronal axis views than visual axis views. This was most evident at 2 mm posterior to the globe (loss of 15 of 54) and at 12 and 15 mm (losses of 10 and 21 of 54, respectively). There were no limitations or lost data points in the 3- to 9-mm range or in any images taken in the coronal axis.

Measurements of the ONSD in the visual axis showed a gradual increase in ONSD along its length from anterior to posterior (Table 1). Optic nerve sheath diameter measurements increased in a linear fashion, with a coefficient of determination of 0.9897.

Discussion

Our results show that coronal axis measurements of the ONSD do not correlate with visual axis measurements, which are consistently larger. Measurements by the coronal axis are more consistent with known anatomy of the inner diameter of the ONS and previously published data. Magnetic resonance imaging measurements of the ON have shown a normal range of 2.7 to 3.2 mm, whereas measurements of the outer diameter of the ONS range from 4 to 5.7 mm and show that the ON and sheath actually decrease in diameter as they course posteriorly. The increase in diameter seen on visual axis measurements can be explained by a number of possible factors. Byrne and Green described this wedge-shaped artifact as secondary to the oblique incidence of ultrasound waves on the borders of the ON. Another and probably very important issue is that there are considerable sound distortions secondary to optical artifacts produced by the anterior segment of the eye, including the cornea and lens. This is not an issue when using coronal views because the sound waves do not pass through these struc-

<table>
<thead>
<tr>
<th>Parameter</th>
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<th>2 mm</th>
<th>3 mm</th>
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<td>n</td>
<td>53</td>
<td>38</td>
<td>53</td>
<td>53</td>
<td>52</td>
<td>44</td>
<td>33</td>
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<td>Mean ONSD, mm</td>
<td>3.4</td>
<td>4.3</td>
<td>4.3</td>
<td>5.2</td>
<td>5.8</td>
<td>6.4</td>
<td>7.4</td>
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<tr>
<td>95% CI, mm</td>
<td>3.2–3.6</td>
<td>3.9–4.7</td>
<td>4–4.7</td>
<td>4.8–5.5</td>
<td>5.3–6.2</td>
<td>5.8–7</td>
<td>6.9–8.2</td>
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CI indicates confidence interval.
Measurements of the Optic Nerve Sheath Diameter

Figure 3. Scatterplot of coronal axis and visual axis measurements of the ONSD. Measurements made in the coronal axis are plotted against visual axis measurements made 3 mm posterior to the sclera. Linear regression and the corresponding coefficient of determination are displayed.

Previous studies that correlated this structure with increased ICP support the theory that this structure is shadowing from the optic disc because increasing ICP would result in papilledema and widening of the artifact. In fact, the possibility that visual axis measurements of the ONSD are actually measurements of the optic disc does not detract from the literature that correlates this measurement to increased ICP but may explain the variability of these studies. The use of an artifact rather than a true anatomic structure could potentially explain the high sensitivity but poor specificity for the test reported in these studies.

As in most areas of sonographic imaging, maintaining perpendicularity of the sound beam to the structures being studied is paramount. Perpendicularity ensures an improved signal-to-artifact ratio, improving image quality and quantification. Hansen and Helmke\(^4\) and Helmke and Hansen\(^5\) performed sonographic examinations of the ON and sheath on dissected anatomic sections and identified the ideal scanning approach at a right angle or perpendicular approach to the nerve. The coronal axis approach provides a cross-sectional view of the ON without the interference of shadowing artifacts from the optic disc and is the scanning approach promoted in the ophthalmic ultrasound literature.\(^3\)

This study had several limitations. The study was designed only to assess for correlation between ONSD values measured between two diagnostic imaging protocols, without a reference standard to show which of the two was more accurate. The lack of an abnormal ONSD also limits the findings of this study.

In summary, visual axis views of the ONS do not correlate with coronal axis views. Evidence supports using coronal axis views when visualizing the ON and ONS. Future studies should compare coronal axis and visual axis approaches with a reference standard to determine the optimum imaging technique.

References


