

Reproducibility of Color Doppler Imaging for Orbital Arteries in Japanese Patients With Normal-Tension Glaucoma

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Abstract: The reproducibility of measurements by color Doppler imaging (CDI) were evaluated in Japanese patients with normal-tension glaucoma. Measurements were taken in the central retinal artery, the ophthalmic artery, and the short posterior ciliary arteries. Reproducibility was evaluated by calculating the coefficients of reproducibility for the peak systolic and end diastolic velocities and for the resistance index. The coefficient of reproducibility was calculated as $|V1 - V2| / \{(V1 + V2) / 2\}$ where V1 is the value of the first measurement and V2 is the value of the measurement taken 48 hours later. In calculating the resistance index of the orbital arteries, the central retinal artery and the short posterior ciliary artery temporal to the optic nerve both had coefficients of reproducibility of 0.04 ± 0.04 (mean \pm standard deviation); the ophthalmic artery and the short posterior ciliary artery nasal to the optic nerve both had coefficients of reproducibility of 0.04 ± 0.05 . The high reproducibility of the CDI technique supports the validity of using CDI in a clinical setting to measure the hemodynamic parameters of small retrobulbar blood vessels. **Jpn J Ophthalmol 1998;42:389-392** © 1998 Japanese Ophthalmological Society

Key Words: Color Doppler imaging, normal-tension glaucoma, orbital vessel, reproducibility, resistance index.

Introduction

The use of color Doppler imaging (CDI)¹⁻³ in the examination of normal-tension glaucoma patients has revealed an increase in the resistance index of such orbital arteries as the central retinal artery and the short posterior ciliary arteries. This new evidence of vascular abnormalities⁴⁻⁷ contributes to our understanding of the pathogenesis of glaucoma. Because the detected abnormalities are subtle, the reproducibility of the CDI technique is of fundamental importance in assessing a true change. Harris et al⁸ evaluated the coefficient of reproducibility for blood flow measurements of orbital arteries and reported

the high reproducibility of the CDI technique. Because the retrobulbar blood vessels are small in diameter and their anatomy may differ among individuals, the use of CDI requires the proficiency of a well-trained examiner to produce accurate measurements. To establish standards for the use of CDI in our institution, we prospectively evaluated the reproducibility of the CDI technique now in use in our department.

Subjects and Methods

Enrolled in the prospective study were normal-tension glaucoma patients who met the following criteria: age between 30 and 85, normal systemic blood pressure, absence of systemic diseases that may cause vascular abnormalities, absence of drugs that may affect hemodynamics in ocular or extraocular vessels, absence of glaucoma medication for the previous 4 weeks, and no history of ocular surgery. Normal-tension glaucoma was defined by: peak intraoc-

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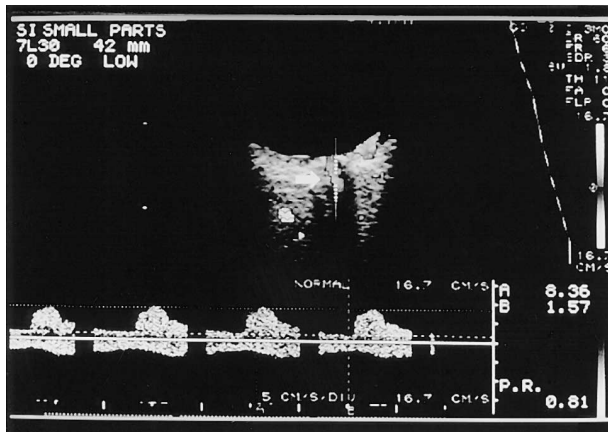


Figure 1. Color Doppler imaging on central retinal artery. Measurement is done at sample gate indicated by arrow. A: peak systolic velocity; B: end-diastolic velocity; PR: resistance index.

ular pressure lower than or equal to 21 mmHg at all times, including a 24-hour phasing; presence of typical glaucomatous visual field defects associated with glaucomatous optic nerve changes; and presence of optic neuropathy not attributable to other ocular or systemic pathology. All patients were Japanese. Informed consent was obtained from each patient before examination by CDI was conducted.

Color Doppler imaging was performed by a single examiner (YN) proficient in CDI technique, using the Siemens Quantum 2000 system (Siemens Quantum, Issaquah, WA, USA) with a 7.5-MHz linear probe. Patients were examined while in supine position. The peak systolic velocity (PSV) and the end diastolic velocity (EDV) were measured in each

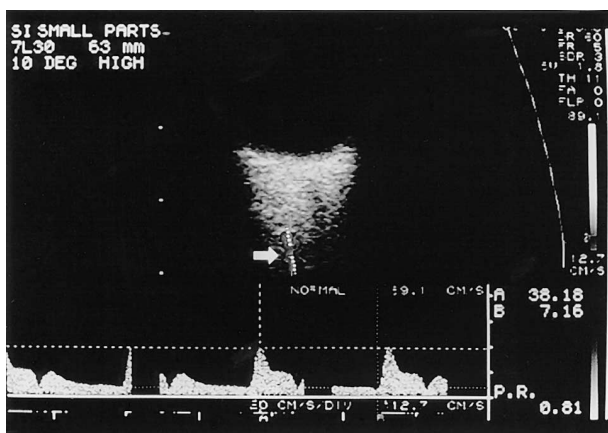


Figure 2. Color Doppler imaging on ophthalmic artery. Measurement is done at sample gate indicated by arrow.

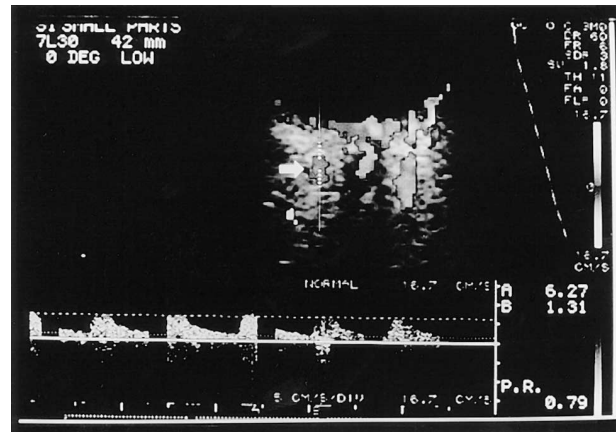


Figure 3. Color Doppler imaging on short posterior ciliary artery nasal to optic nerve. Measurement is done at sample gate indicated by arrow.

blood vessel and the resistance index (RI) was calculated as $RI = (PSV - EDV) / PSV$. Measurements were taken in the central retinal artery, the ophthalmic artery, and the short posterior ciliary arteries. The central retinal artery, seen in the shadow of the optic nerve, was examined approximately 3 mm posterior to the eyeball (Figure 1). The ophthalmic artery was examined approximately 10 mm posterior to the eyeball, where the shadows of the ophthalmic artery and the optic nerve intersected (Figure 2). Short posterior ciliary arteries, both temporal to and nasal to the optic nerve, were examined approximately 5 mm posterior to the eyeball (Figures 3, 4). Measurements were taken between 10:00 A.M. and

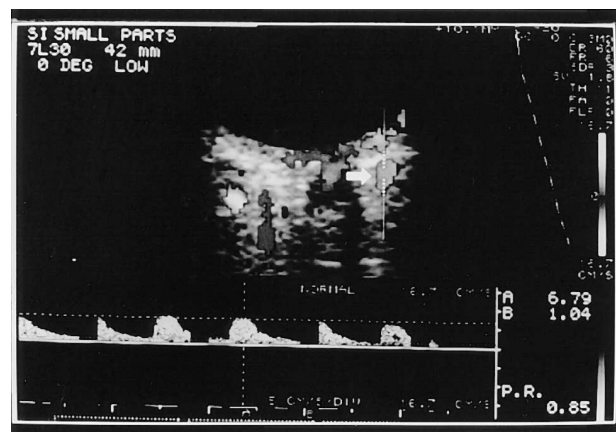


Figure 4. Color Doppler imaging on short posterior ciliary artery temporal to optic nerve. Measurement is done at sample gate indicated by an arrow.

12:00 P.M. and again 48 hours later. Measurements were taken in both eyes of each normal-tension glaucoma patient; the eye with the worse mean deviation, as calculated with the Humphrey Field Analyzer, was selected for further evaluation. At each measurement, the patient's systemic blood pressure was monitored using an automatic device with an internal recording microphone (HEM-705CP, Omron, Matsuzaka).

Reproducibility was evaluated by calculating coefficients of reproducibility for the PSV, EDV, and RI measurements of each vessel, and for systolic and diastolic systemic blood pressure values. The coefficient of reproducibility was calculated as $|V1 - V2| / \{(V1 + V2)/2\}$, where V1 is the value of the first measurement and V2 is the value of the measurement 48 hours later.

Results

Enrolled in the study were 34 normal-tension glaucoma patient, 15 men and 19 women. Their ages ranged from 32 to 83 years (average 58.9 years). Table 1 shows the mean (\pm standard deviation) of each set of measurements and each calculated coefficient of reproducibility. In calculating the resistance index of the orbital arteries, the central retinal artery and the short posterior ciliary artery temporal to the optic nerve both had coefficients of reproducibility of 0.04 ± 0.04 ; the ophthalmic artery and the short posterior ciliary artery nasal to the optic nerve both had coefficients of reproducibility of 0.04 ± 0.05 .

Discussion

The coefficients of reproducibility for RI measurements of orbital arteries in Japanese patients with normal-tension glaucoma averaged 0.04 in our study, indicating a relatively high reproducibility for our CDI technique. Harris et al⁸ previously reported a similarly high reproducibility of CDI as kappa statistics: the coefficients of reliability for RI were 4% for the ophthalmic artery, 11% for the central retinal artery, and 38% for the short posterior ciliary artery. Tamaki et al⁹ using the same formula of reproducibility index as ours, reported that the reproducibility of CDI for the ophthalmic artery in Japanese volunteers averaged 10.4% for V_{max} or PSV, 9.2% for V_{min} for EDV, and 4.1% for RI. Rojanapongpun et al¹⁰ also reported the high reproducibility of the CDI technique for the ophthalmic artery.

The coefficients of reproducibility for PSV and EDV measurements ranged from 0.10–0.30 in our study, indicating the reproducibility was better for

Table 1. Measurements and Coefficients of Reproducibility in 34 Cases of Normal-Tension Glaucoma

	First Measurement	Second Measurement	Coefficients of Reproducibility
Orbital arteries			
CRA			
PSV	7.53 \pm 1.99	7.21 \pm 2.57	0.23 \pm 0.14
EDV	1.83 \pm 0.66	1.71 \pm 0.71	0.30 \pm 0.21
RI	0.75 \pm 0.08	0.76 \pm 0.08	0.04 \pm 0.04
OA			
PSV	29.56 \pm 5.28	30.42 \pm 6.81	0.10 \pm 0.10
EDV	7.97 \pm 3.07	7.69 \pm 3.36	0.20 \pm 0.29
RI	0.73 \pm 0.08	0.75 \pm 0.07	0.04 \pm 0.05
NPCA			
PSV	7.22 \pm 2.36	7.20 \pm 2.15	0.15 \pm 0.13
EDV	2.03 \pm 0.90	2.06 \pm 0.88	0.19 \pm 0.20
RI	0.72 \pm 0.07	0.71 \pm 0.07	0.04 \pm 0.05
TPCA			
PSV	7.13 \pm 2.27	7.44 \pm 2.19	0.18 \pm 0.17
EDV	1.97 \pm 0.81	2.09 \pm 0.74	0.23 \pm 0.20
RI	0.72 \pm 0.07	0.71 \pm 0.07	0.04 \pm 0.04
Systemic BP			
Systolic	123.2 \pm 19.7	119.0 \pm 19.0	0.11 \pm 0.07
Diastolic	76.0 \pm 10.0	73.4 \pm 9.4	0.10 \pm 0.08

Values are mean \pm standard deviation.

CRA: central retinal artery, OA: ophthalmic artery, NPCA: short posterior ciliary artery nasal to optic nerve, TPCA: short posterior ciliary artery temporal to optic nerve, PSV: peak systolic velocity (cm/sec), EDV: end diastolic velocity (cm/sec), RI: resistance index, BP: blood pressure (mmHg).

RI than for PSV and EDV. This finding agrees with those of other investigators except that the coefficients of reproducibility did not differ as much among the vessels as reported elsewhere.^{8–11} One reason for the variability of measurements among the blood vessels seems to be insufficient correction of the angle between the artery being measured and the Doppler beam, which must be corrected manually following each measurement. Because the angulation occurs three-dimensionally and we can correct it in only two dimensions or from a B-mode image, the correction is likely to be insufficient. Avoiding this type of error requires consistency in the positioning of both the patient and the CDI probe as well as in the portion of each blood vessel actually being measured. The angle-dependent error is inevitably involved in PSV and EDV measurements. It can be eliminated by employing RI as an index of hemodynamics;⁸ we used the latter index as the main measure of outcome in the current study.

The reproducibility of other devices measuring ocular hemodynamics has been reported by several authors. Joos et al¹² reported that the coefficient of variation was 7% for velocity and 10% for flux,

when the optic nerve head was measured once with scanning laser Doppler flowmetry.¹³ Nicolela et al¹⁴ also reported that the reproducibility of retinal and lamina cribrosa measurements by scanning laser Doppler flowmetry with a 10 × 10 pixel target was good, with reliability coefficients for different measurements ranging from 0.70–0.85. Using laser speckle interferometry, another measurement modality, Tamaki et al¹⁵ reported that the coefficient of reproducibility was 8.7–11.7% for 1-minute interval measurements on the optic nerve head and the choroid, and 9.7–13.0% for 24-hour interval measurements. Although scanning laser Doppler flowmetry and laser speckle interferometry are used to measure intraocular blood vessels rather than retrobulbar blood vessels, the reproducibility of the CDI technique remains substantially higher.

The current study demonstrates the relatively high reproducibility of the CDI technique when a proficient examiner takes orbital artery measurements 2 days apart in Japanese patients with normal-tension glaucoma. The pathogenesis of normal-tension glaucoma still remains unknown. A vascular theory has long been considered. The dominant thesis is that vasospasm or inappropriate vasoconstriction causes inadequate perfusion, resulting in tissue death at the optic nerve head. The reported change in arterial abnormalities in glaucomatous eyes is relatively small, however.^{1–3} For example, Harris et al¹ reported an RI change of 0.05 as significant in normal-tension glaucoma patients. Therefore, the reproducibility of the CDI technique is a matter of concern. In this regard, our results support the validity of using CDI in a clinical setting to measure the hemodynamic parameters of small retrobulbar blood vessels.

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