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Estimating Ocular Hypertension and Glaucoma With Optic Nerve Tortuosity on Conventional Orbital Magnetic Resonance Imaging

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Glaucoma is the second leading cause of blindness worldwide. Additionally, in contrast to cataract, which is the number one cause, blindness from glaucoma is irreversible. Because the progression of glaucoma is prolonged and may remain silent even for decades, this disease has been referred to as the ''sneaky thief of sight'' [1]. It is estimated there are greater than 60 million people worldwide with glaucoma-related optic neuropathy and that 8.4 million are likely to become blind [2].

Glaucoma consists of a combination of neurodegenerative changes, affecting both the retina and the central visual pathways [3]. The most common type of glaucoma is primary open-angle glaucoma, which includes high-tension glaucoma. Intraocular pressure (IOP) of 21 mm Hg or higher is defined as ''increased intraocular tension'' [4].

Glaucoma is a complicated disease, and the diagnosis can be made by using a combination of multiple factors, including family history. Symptoms can be summarized as hazy or blurred vision, the appearance of rainbow-coloured circles around bright lights, eye and head pain, nausea and vomiting, and sudden loss of sight.

Unfortunately, diagnosis of glaucoma sufficiently early remains the main problem. According to the literature, the first signs of visual field impairment (which is still the gold standard for diagnosis) appear when a significant amount (40%−50%) of retinal ganglion cells has been irreversibly lost [5,6].

In several recent studies, attempts have been made to describe magnetic resonance imaging (MRI) signs of glaucoma. These studies were based on functional, spectroscopic, and diffusion tensor imaging [1,3−10]. In addition, an article on optic nerve volume changes in glaucoma can be found in the literature [11]. To our knowledge, our evaluation of the tortuosity index (TI) of the optic nerve in patients with glaucoma is the first of its kind. Increased tortuosity of the optical nerve is a sign of neurofibromatosis disease [12−14].

The aim of this study was to determine the optic nerve TI for 2 groups of patients: patients with increased IOP and those with glaucoma.

Methods

To obtain study data, the archives of the Eye Clinic of our institute was retrospectively searched for the period from January to August 2017. All patients with glaucoma had been diagnosed according to the clinical practice guidelines for glaucoma in Canada. The ocular hypertension group consisted of patients with an IOP of 21 mm Hg or greater in 2 consecutive measurements. Age- and sex-matched healthy subjects were randomly evaluated to be included in the control groups.

All cases included in the study were selected from non-neurofibromatosis patients. All control subjects included in the study were individuals without neurofibromatosis and glaucoma and those with normal IOP.

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All patients with increased ocular tension were being followed up with certain time intervals without any treatment. All patients with glaucoma were being followed up as well, but with treatment.

Diagnostic Criteria for Glaucoma

In our study, a comprehensive glaucoma examination was performed after obtaining patient history: examination of inner eye pressure, complete field of vision, and thickness of the cornea, as well as examination of the eye fundus with optical coherence tomography were performed. For a definitive diagnosis, an optic nerve defect, optic nerve fiber layer defect, or visual field loss alone had to be present. Elevated IOP was not required [15].

Calculating Optic Nerve Tortuosity Index

During the TI measurements, the radiologists did not know which group the images belonged to (control, increased IOP, or glaucoma group) because we did not want these data to affect the measurements.

To calculate TI, conventional orbital MRI sequences were used. Each examination consisted of axial T1 and T2, coronal T1, and coronal STIR images. Slice thickness was 3–4 mm.

No medication, including contrast media, was used during the examination.

No participant had a medical device (ie, drainage device) and a history of surgery.

The best visualized axial MRI sequences were chosen for 2-dimensional calculation, and additional corresponding coronal slices were used for 3-dimensional calculation of optic nerve tortuosity.

The eye with the higher pressure was chosen to calculate the TI in patients with increased ocular tension. All patients in this group had increased ocular tension in both eyes.

We calculated the mean TI if glaucoma was present in both eyes (44 of 45 patients).

In the 2-dimensional calculation, 2 distances were determined. The first was the shortest distance between the 2 terminal points of the optic nerve (from the globe to the optic chiasm). The second was the sum of all of the subsegments of the optic nerve that were not in the same direction.

In the 3-dimensional calculation, the same method was used but all subsegments were calculated with 3 dimensions. This time, each subsegment's 1-dimension length was calculated to be the square root of the sum of the squares of the apparent coordinate value minus the previous coordinate value of each dimension.

An estimation of the tortuous length of the nerve was computed by summing the short segment lengths, as the Euclidean distance between pairs of points on adjacent coronal slices. Finally, the TI was computed as the ratio between these lengths minus 1, modeled on a similar measure of arterial tortuosity [16] (Figure 1).

For instance, let us calculate TI in Figure 2:

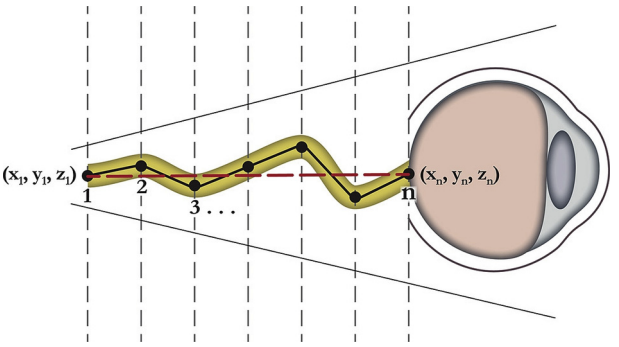

Figure 1. Sagittal plane illustration shows calculating 3-dimensional tortuosity by using corresponding coronal slices.

In 2-dimensional calculation:

The lengths of the 3 subsegments of the optic nerve are 4.46 mm, 9.75 mm, and 16.28 mm.

Their sum will be 30.49 mm.

The shortest distance between the 2 terminal points of the optic nerve (from the globe to the optic chiasm) is 28.65.

$$\mathrm{TI} = (30.49/28.65) - 1 * 100 = 6.4$$

The 3-dimensional calculation for the same optic nerve TI:

$$\begin{aligned}\mathrm{TI} = &\left[\sqrt{(2^2+4^2+1^2)} + \sqrt{0^2+10^2+7^2}\right. \\ &\left. + \sqrt{8^2+14^2+4^2} \Big/ \sqrt{10^2+28^2+7^2} - 1\right] * 100 \\ &= (33.4/30.54-1) * 100 = 9.36\end{aligned}$$

Each group's (glaucoma and ocular hypertension) mean TI was compared with its own control group separately. In addition, the mean optic nerve tortuosity values of patients with glaucoma and increased ocular hypertension were compared with each other.

Figure 2. A 65-year-old patient with glaucoma with optic nerve tortuosity of 6.4%.