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Clinical Study

Optical coherence tomography of the optic nerve head detects acute changes in intracranial pressure

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ABSTRACT

We aimed to determine if there are measurable objective changes in the optic nerve head (ONH) immediately after cerebrospinal fluid (CSF) drainage in a prospective case-series of five patients undergoing a clinically indicated lumbar puncture (LP) for diagnosis of idiopathic intracranial hypertension. A Cirrus high-definition optical coherence tomography machine (Carl Zeiss Meditec, Dublin, CA, USA) was used to acquire images in the lateral decubitus position. Optic disc cube and high-definition line raster scans centered on the ONH were obtained immediately before and after draining CSF, while the patient maintained the lateral decubitus position. Measured parameters included retinal nerve fiber layer (RNFL) thickness, peripapillary retinal pigment epithelium/Bruch's membrane (RPE/BM) angulation, transverse neural canal diameter (NCD) and the highest vertical point of the internal limiting membrane from the transverse diameter (papillary height). The mean (±standard deviation) opening and closing CSF pressures were 34.3 ± 11.8 and 11.6 ± 3.3 cmH_2O, respectively. Mean RNFL thickness (pre LP: 196 ± 105 μm; post LP: 164 ± 77 μm, p = 0.1) and transverse NCD (pre LP: 1985 ± 559 μm; post LP: 1590 ± 228 μm, p = 2.0) decreased in all subjects, but with non-significant trends. The RPE/BM angle (mean change: 5.8 ± 2.0 degrees, p = 0.003) decreased in all subjects. A decrease in papillary height was seen in three of five subjects (mean: pre LP: 976 ± 275 μm; post LP: 938 ± 300 μm, p = 0.9). Our results show a measurable, objective change in the ONH after acute lowering of the lumbar CSF pressure, suggesting a direct link between the lumbar subarachnoid space and ONH regions, and its potential as a non-invasive method for monitoring intracranial pressures.

1. Introduction

It is well established that chronic elevation of intracranial pressure (ICP) results in biomechanical changes in the optic nerve head (ONH), manifesting clinically as papilledema. [1] However, the time course of structural changes in the ONH with elevated ICP has not been well studied. It is not known whether acute ICP changes will cause dynamic measurable changes in the ONH. The clinical assessment for papilledema even by an experienced ophthalmologist has a poor negative predictive value for acute elevation in ICP [2].

Optical coherence tomography (OCT) is a non-invasive imaging method that emits near-infrared light and selectively processes light reflected directly from tissues to create high resolution *in vivo* cross-sectional representations of anatomical structures [3]. The next generation high-definition spectral domain optical coherence tomography (HD-OCT) have enabled better axial resolution, and three-dimensional *in vivo* imaging of the sub-structures of the ONH [4]. HD-OCT has been previously reported as a sensitive tool in the detection of papilledema or disc edema from other etiologies [4,5]. This study aims to determine whether HD-OCT detects objective measurable changes in the ONH with an acute lowering of ICP.

2. Methods

2.1. Patient selection

This prospective observational study was conducted in consecutive patients with suspected idiopathic intracranial hypertension (IIH) referred to Baylor Saint Luke's Medical Center, USA, for a lumbar puncture (LP). Our inclusion criteria were patients

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18 to 65 years old with suspected IIH, based on Friedman criteria, and needing a LP to confirm the diagnosis [6,7]. Patients were excluded if they had neuro-ophthalmological conditions that would preclude an OCT examination or interpretation, including cataracts, retinopathy, or optic atrophy. Institutional review board approval was obtained prior to initiation of the study. Written informed consent was obtained from all subjects.

2.2. Procedure

LP was performed in the left lateral decubitus position by an experienced neurologist. All ICP and HD-OCT measurements were taken with legs extended and after ensuring that the subjects were parallel to the axis of the floor. The opening pressure was measured after waiting about 5 minutes to ensure stability of the ICP. HD-OCT scans were performed using a Cirrus HD-OCT (Carl Zeiss Meditec, Dublin, CA, USA). The device was positioned sideways to acquire images in the lateral decubitus position. Sharply-focused optic disc cube 200 × 200 and HD five line raster scans centered on ONH were obtained immediately before needle insertion, and after draining CSF while the subject remained in the left lateral decubitus position. We tested only the right eye of each subject for consistency. Parameters measured included average retinal nerve fiber layer (RNFL) thickness, peripapillary retinal pigment epithelium/Bruch's membrane (RPE/BM) angulation, transverse neural canal diameter (NCD) and papillary height. The average thickness for the entire RNFL circumference was calculated using manufacturer software provided with HD-OCT. The RPE/BM positive angulation is an angle formed between a line drawn tangential to the curve of unaltered RPE/BM in the peripapillary retina furthest from the ONH and the altered border adjacent to neural canal opening (NCO) [8]. We defined transverse NCD as the horizontal diameter of NCO measured at the level of RPE/BM. Papillary height was defined as a vertical line from the highest point of internal limiting membrane at the NCO to the NCD. All measurements were made by an ophthalmologist experienced in OCT, who was blinded to the corresponding ICP data. Figure 1 depicts the landmarks used to measure RPE/BM angulation, transverse NCD and papillary height in a subject immediately before and after LP.

2.3. Statistical analysis

Data are presented as mean ± standard deviation after testing for normal distribution. Pre and post LP data were compared using a paired t-test. Two-tailed p-values are presented.

3. Results

All five study subjects were women with a mean age of 30.4 ± 5.3 years. The mean opening and closing CSF pressures were 34.3 ± 11.8 and 11.6 ± 3.3 cmH_2O, respectively. Figure 2 demonstrates a three-dimensional representation of optic disc

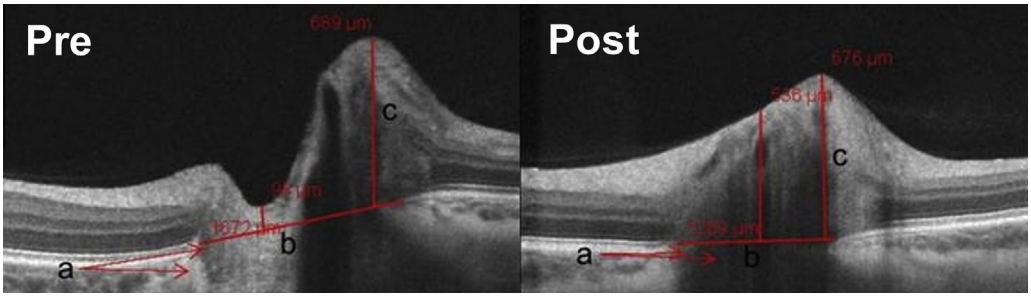

Fig. 1. Cirrus high definition optic coherence tomography (Carl Zeiss Meditec, Dublin, CA, USA) acquired images of optic nerve head substructures using high definition five line raster scans centered on the optic disc in a subject immediately before and after cerebrospinal drainage. Each image shows landmarks for (a) RPE/BM angulation, (b) transverse neural canal diameter and (c) papillary height. There is a measurable decrease in RPE/BM angulation, transverse neural canal diameter and papillary height in the post LP (right) scan compared to the pre LP (left) scan. LP = lumbar puncture, RPE/BM = retinal pigment epithelium/Bruch's membrane.

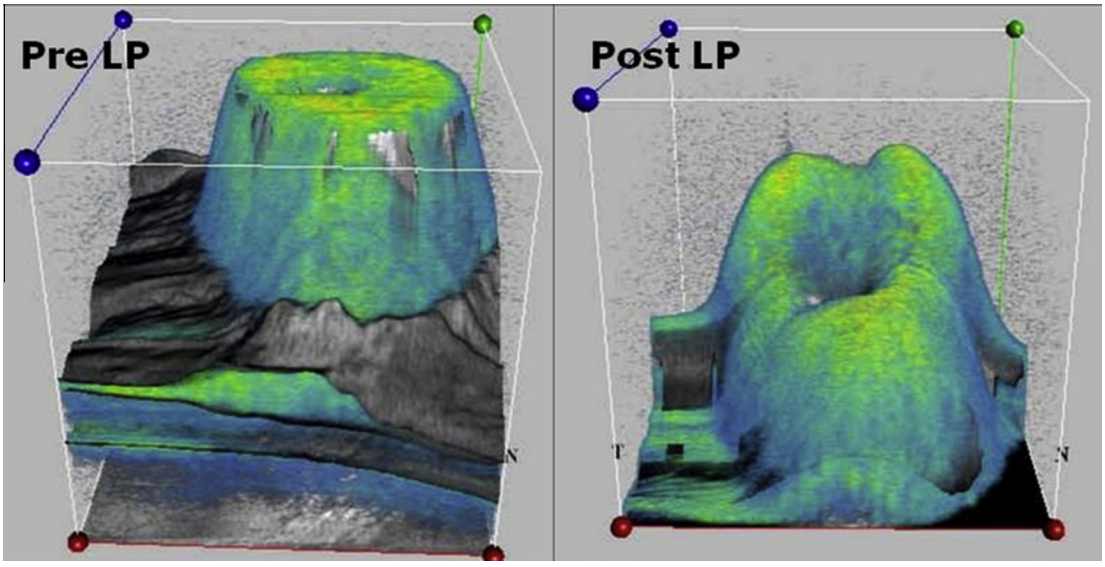

Fig. 2. A three-dimensional representation of optic disc cube 200 × 200 generated by the Cirrus high definition optic coherence tomography (Carl Zeiss Meditec, Dublin, CA, USA) software in a subject with measurements taken before (left) and after (right) lumbar puncture (LP).