Morphometry of the retrobulbar human optic nerve: comparison of 3T MRI with conventional sonography

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Introduction

The optic nerve (ON) is surrounded by subarachnoidal cerebrospinal fluid (CSF) and dura mater. With age and under certain pathologic conditions, such as intracranial hypertension, glaucoma or papilledema, the diameter of the ON and its CSF sheath may change [1,2]. Noninvasive diagnosis of the ON sheath by means of ultrasonography has been described. However, it is known to depend on personal experience and to be subjected to interobserver and test–retest variability [3]. Previous studies using MRI techniques for investigation of the ON typically suffered from long acquisition times of between 4 minutes and 15 minutes, which may lead to artifacts and degradation of spatial resolution caused by the motion of the eyes [4]. The purpose of this study was to compare a very fast half Fourier-acquired single shot turbo spin echo (HASTE)-sequences at 3T MRI with conventional sonography of the retrobulbar optic nerve to analyze optic nerve dimensions.

Methods

33 healthy volunteers with a median age of 25 years underwent high resolution MRI of the right eye on a 3T Trio system (Siemens Medical Systems, Erlangen, Germany). Transversal and sagittal T2-weighted turbo spin echo (TSE) sequences with good soft tissue contrast were used for planning (TR/TE 4000/123 ms, nominal in-plane resolution 0.41 x 0.47 mm^2, slice thickness 5 mm, TA 1:06 min. (transversal) and 1:22 min. (sagittal), respectively.) The diagnostic HASTE sequences were acquired in straight gaze perpendicular to the optic nerve within 5 mm, 10 mm and 15 mm behind the eye (Figure 1, TR/TE 1500/146 ms, TA 1.5 sec., number of excitations 1, bandwidth 195 Hz/pixel, FOV 23 x 18 cm^2, Matrix 512 x 367, nominal spatial resolution 0.45 x 0.49 mm^2, interpolated to a higher matrix size of 2048 x 1468 with a pixel size of 0.11 x 0.12 mm^2, slice thickness 3 mm). A-scan ultrasonography and B-scan ultrasonography were repeated three times in straight gaze. MRI studies were analyzed independently twice by two radiologists and completely repeated in a subset of 10 subjects. 95% confidence intervals and coefficients of variation were calculated.

Results

The mean MRI scanning time was 8.42 minutes (± 1.84 SD, range 5 – 16 min.). HASTE-sequences yielded high contrast between cerebrospinal fluid and optic nerve parenchyma (Figure 1). Acquisition time for the diagnostic sequence was 1.5 seconds per slice. Optic nerve diameters decreased from 3.23 mm at 5 mm to 2.67 mm at 15 mm behind the eye. The sheath diameters decreased from 5.72 mm to 3.98 mm. When a second radiologist re-measured the optic nerve diameters in the original scans, the coefficients of variation ranged between 4% anteriorly and 7% posteriorly. For the sheath they varied between 3% and 7%, respectively. When the whole MRI procedure was repeated in a subset of subjects, the coefficients of variation were similar: they ranged between 3% and 5% for the nerve and between 2% and 6% for the sheath. Compared to the MRI readings, ultrasonographic measurements consistently yielded smaller diameters. In the A-scan mode, the diameter of the retrobulbar optic nerve was 2.31 mm, and 4.08 mm of the sheath. The coefficients of variation were 9% and 13%, respectively. Slightly higher diameters of the optic nerve and its sheath were obtained in the B-scan mode.

Discussion

High-resolution MRI at 3.0 T depicts the optic nerve and its sheath within the full intraorbital track with high contrast in 1.5 sec. acquision time per slice. Narrowing of the nerve and its sheath as they approach the orbital apex is clearly demonstrated. In addition to the high contrast between CSF and nerve parenchyma the main advantage of HASTE-sequences is their unprecedented short acquisition time avoiding blurring by uncontrolled eye movements. The coefficients of variation were surprisingly small for a biologic measure indicating high precision and reproducibility. HASTE-sequences appear particularly appropriate to investigate the retrobulbar optic nerve complex and may be useful for quantifying axonal loss within the optic nerve and for assessment of differential diagnoses in optic nerve disease.

References

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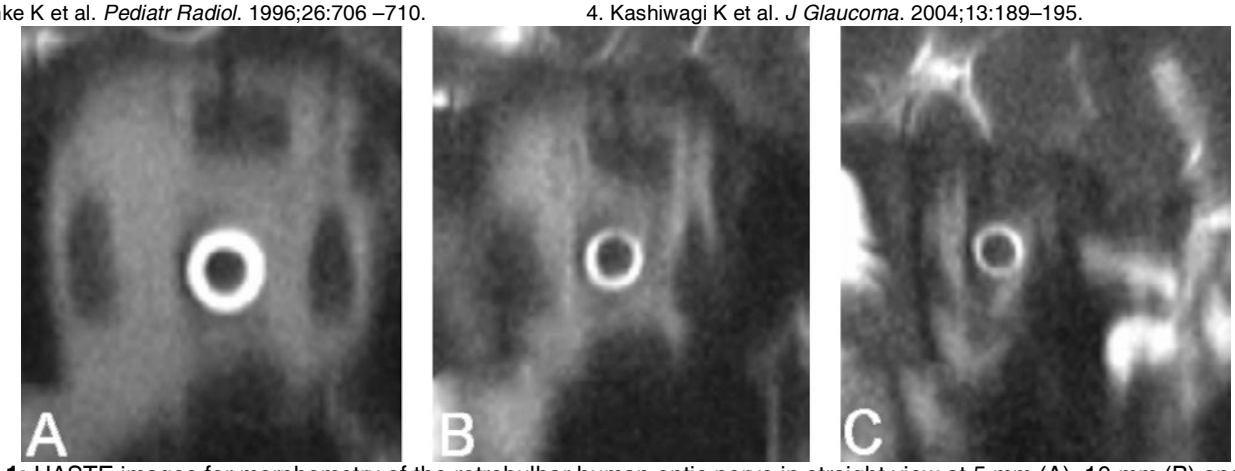

Figure 1: HASTE images for morphometry of the retrobulbar human optic nerve in straight view at 5 mm (A), 10 mm (B) and 15 mm (C) behind the eye. The bright liquor ring is well delineated and exhibits a high contrast to its surrounding tissue.