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MR GONIOSCOPY: A NEW DIAGNOSTIC TOOL FOR EVALUATING GLAUCOMA

Radiology

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ABSTRACT

INTRODUTION: Slit-lamp biomicroscopy, performed in conjunction with the conventional hand held gonioscopy has been an established technique to assess the anatomy of the angle of anterior chamber. These techniques are subjective, however. Diagnosis depends on the skill of the operator. Ultrasonographic (US) biomicroscopy, optical coherence tomography (OCT) and scanning peripheral anterior chamber analysis allow quantitative objective assessment of the cross-sectional anatomy of the anterior chamber angle. To the best of our knowledge, no study has been performed using circular polarized array head coil for assessment of the angle of anterior chamber in glaucomatous eyes. **AIM:** The purpose of the study was to determine the accuracy of Half-Fourier single-shot turbo spin echo (HASTE) magnetic resonance (MR) imaging performed with a circular polarized array coil in the diagnosis of narrow anterior chamber angle in patients with glaucoma.

MATERIALAND METHODS: 30 recruited patients underwent slit-lamp biomicroscopy and MR Gonioscopy.

RESULTS: There was substantial agreement between MR gonioscopy and slit-lamp biomicroscopy in the classification of anterior chamber angles as narrow or open (Kappa coefficient-0.773).

CONCLUSION: MR gonioscopy has substantial potential as a technique used to evaluate glaucoma.

KEYWORDS

INTRODUCTION

Glaucomas comprise of a group of ocular disorders of varied aetiology united by a clinically characteristic optic neuropathy with potentially progressive, clinically visible changes at the optic nerve head (ONH) which can easily be detected on fundoscopic examination. While visual acuity is initially spared, progression can lead to complete loss of vision; the constellation of clinical features is diagnostic (1).

Laser or non-laser glaucoma surgery is frequently required to reduce the intraocular pressure with chronic angle closure glaucoma (2, 3). Slit-lamp biomicroscopy, performed with the conventional hand held gonioscopy has been an established technique to assess the anatomy of the angle of anterior chamber. Van Herick technique has been used to diagnose narrow or occlusive anterior chamber angle (4, 5). These techniques are subjective, however. Diagnosis depends on the skill of the operator.

Ultrasonographic (US) biomicroscopy, optical coherence tomography (OCT) and scanning peripheral anterior chamber analysis enable quantitative objective assessment of the cross-sectional anatomy of the anterior chamber angle (6). However, these investigations have not gained widespread acceptance (7).e

Wider availability and access to clinical 1.5-T magnetic resonance (MR) imaging units has recently increased worldwide. Half-Fourier single-shot rapid acquisition with relaxation enhancement MR imaging performed with a microscopy coil has been shown to have substantial potential for evaluation of the anterior chamber region of glaucomatous eyes. There is strong agreement between MR gonioscopic and slit-lamp biomicroscopic results in the evaluation of the anterior chamber angle. Moreover, MR gonioscopy depicts details of the peripheral iris, depth of the central anterior chamber and thickness of the lens (8).

To the best of our knowledge, no study has been performed using circular polarized array head coil for assessment of the angle of anterior chamber in glaucomatous eyes.

MATERIALAND METHODS

This study was conducted in accordance with the Helsinki treaty and informed consent was obtained from all patients.

All cases attending the eye OPD in a tertiary care teaching hospital formed the study population. Patients diagnosed with primary open and narrow angle glaucoma who were sufficiently controlled with treatment (either medical or surgical) formed the sampling population. Systematic random sampling was used as the sampling technique. In it, every fifth patient diagnosed with glaucoma irrespective of the type, underwent the diagnostic test in question (MR Gonioscopy).

Taking handheld gonioscopy as gold standard and estimating the sensitivity and specificity of MR gonioscopy with 95% confidence interval and precision of 5% around the sensitivity of MR gonioscopy as 98 % (8), the minimum sample size required was 30 cases.

The study was conducted over a period of two years. The nature of study was diagnostic test evaluation. Labelling patients as glaucoma was on the basis of glaucomatous optic disc cupping on fundoscopy and visual field abnormalities.

Excluded patients from the study were having nystagmus, secondary causes of glaucoma, viz. uveitis, trauma or patients having contraindications to MR Imaging viz. metallic implants, active pacemaker, implantable ventricular assisted devices, cochlear implants, intra-cerebral aneurysm clips, free particulate iron in the optic globe, claustrophobia.

The various clinical details that were recorded for each patient were age, sex of the patient, history of prior eye surgery, best corrected visual acuity. Detailed information was obtained and recorded.

All subjects underwent ophthalmological examination including:

1. Intraocular pressure measurement by Goldman Applanation Tonometry.
2. Slit lamp biomicroscopy using Appasamy slit lamp
3. Gonioscopy using Volk 4 mirror gonioprism
4. Fundoscopy with evaluation of the cup to disc (C/D) ratio.

The angle of anterior chamber was measured using slit lamp and handheld gonioscopy. The angle grades were assigned according to the Shaffer system as shown in table 1 (4).

Grade 4	45° to 35° angle	Wide open
Grade 3	35° to 20° angle	Wide open
Grade 2	20° angle	Narrow
Grade 1	≤10° angle	Extremely narrow
Slit	0° angle	Narrowed to slit
*Based on the angular width of the angle recess.		

Table 1: Shaffer System* of grading the angle of anterior chamber

All MRI examinations were performed on the same 1.5-Tesla MR unit (Siemens: Magnetom Symphony Maestro class with a Niobium-Titanium superconductor magnet)) using a circular polarized array head coil. Subjects were asked to close their eyes and avoid any deliberate eye movements during image acquisition.

- **Image analysis**

The measurements were taken in the 2.5 mm thick HASTE axial

images. The axial section passing through the level of the optic discs was analysed.

- **Measurement of the angle of anterior chamber**

For angle measurement (Fig 1), one line was drawn along the posterior surface of the cornea extending peripherally till the angle of anterior chamber. Another line was drawn along the anterior surface of the most peripheral part of the iris at the level of scleral spur. The angle between these two lines was taken as the angle of anterior chamber. Separate measurements were taken for each eye.The angle grade was assigned according to the Shaffer system of grading.

- **Measurement of the thickness of lens**

Thickness of the lens was assessed in the central part of the lens where the thickness is maximum.

- **Depth of the anterior chamber (AC)**

Depth of the AC was assessed in the central part of the anterior chamber where it is maximum.

STATISTICALANALYSIS

Statistical analysis was performed using commercially available statistical package for the social science (SPSS) version 22.0 and Epi Info™ 7 softwares.

RESULTS

Patients aged between 20 and 70 years with a mean age 49±14.9 yrs. There were 20 males (66.7%) and 10 females (33.3%) in the study group.

All 30 patients (60 eyes) underwent MR gonioscopy. A total of 14 (23.3%) eyes showed narrow angle (grade 0,1 and 2) comprising of grade 1 in 3 eyes (5 %) , grade 2 in 11 eyes (18.3 %). 46 eyes showed open angle (grade 3 and 4) on MR gonioscopy, comprising of grade 3 in 33 eyes (55 %) and grade 4 in 13 eyes (21.7 %). The radiologist at the time of evaluating the MRI images was blinded of the slit lamp biomicroscopy results.

All patients were evaluated by slit lamp in conjunction with hand held gonioscopy. Anterior chamber (AC) angle was narrow (Grade 0, 1 and 2) in 15 eyes (25%) and open (Grade 3 and 4) in 45 eyes (75%).

MR Gonioscopy	Hand held gonioscopy					Total
	0	1	2	3	4	
0	0	0	0	0	0	0
1	1	2	0	0	0	3
2	0	4	5	2	0	11
3	0	0	3	16	14	33
4	0	0	0	3	10	13
Total	1	6	8	21	24	60

Table 2: Comparison of AC Angle grade using MR Gonioscopy and hand held gonioscopy

The overall accuracy of MR gonioscopy for correctly classifying the AC angle was found to be (12+43)/60 = 91.7 %. Cohen kappa coefficient was 0.773 (Table 3). Cohen statistics were calculated to analyze agreement between MR gonioscopy and slit-lamp biomicroscopy. Values of 0.61–0.80 indicated substantial agreement.

MR Gonioscopy	Hand held gonioscopy		Total	Cohen Kappa coefficient
	Narrow Angle (Grade 0,1,2)	Open Angle (Grade 3,4)		
Narrow Angle (Grade 0,1,2)	12	2	14	0.773
Open Angle (Grade 3,4)	3	43	46	
Total	15	45	60	

Table 3: Comparison of narrow and open angle on MR & hand held gonioscopy

The results of MR gonioscopy and slit lamp biomicroscopy were correlated substantially in the evaluation of the anterior chamber angle (Table 4). MR gonioscopy had high specificity (95.6%) values with negative predictive value of 93.5%. It meant that this technique is highly accurate in ruling out the diagnosis of narrow angle. This technique can also assess the configuration of the peripheral iris, viz.- regular, steep or queer, bowing anteriorly.

Parameter	Value (%)	95% Confidence Interval (%)	
		Lower limit	Upper limit
Sensitivity	80	51.4	94.7
Specificity	95.6	83.6	99.2
PPV	85.7	56.2	97.5
NPV	93.5	81.1	98.3

Table 4: sensitivity, specificity, positive predictive value (PPV), & negative predictive value (NPV) of MR gonioscopy in detection of narrow angle.

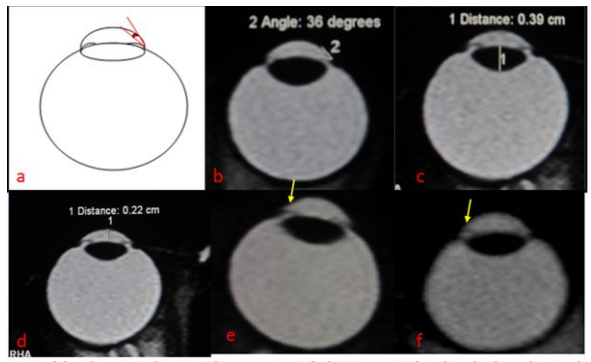

Fig 1 (a) Schematic showing the anatomy of the anterior chamber (AC) angle. Angle between the two red lines represents the angle of the anterior chamber; (b) Measurement of the AC angle; (c) Electronic calliper to measure the thickness of the lens; (d) Measurement of the depth of the anterior chamber; (e) Open angle with flat (arrow) peripheral iris configuration and (f) forward bowing peripheral iris configuration.

The anterior chamber angle in the narrow angle eyes (n=14) was 14.369 ± 4.041 degree; in the eyes with open angle (n=46), it was estimated to be 31.209 ± 6.446 degree. The p-value for the difference between these two means was <0.0001-which is highly significant.

Mean AC depth for narrow angle glaucoma patients was 0.217±0.074 cm, whereas for open angle glaucoma patients, it was 0.292±0.055 cm. The P-Value is .000071. The result is significant at $p < 0.05$.

Mean thickness of lens for narrow angle glaucoma patients was 0.420± 0.031 cm, whereas for open angle glaucoma patients, it was 0.356±0.041 cm. The P-Value is < 0.00001. The result is significant at $p < 0.05$.

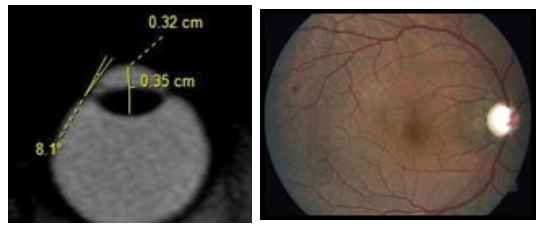

Fig 2: A 62 yrs old man with glaucoma : T2W HASTE axial images of right eye show grade 1(extremely narrow) chamber angle and steep peripheral curvature of the iris. Fundoscopy of right eye reveals pale optic disc with cup to disc ratio (C/D)of 0.3:1 with thinned and pale neuro retinal rim (NRR) in all four quadrants. Conventional gonioscopy showed AC angle narrowed to slit (Gd 0)

DISCUSSION

In the present study, the depth of the anterior chamber was found to be significantly reduced (p-0.000071) in the eyes with narrow angle. These findings were in accordance with the results of study conducted by Lee et al. (9).

Our study revealed the mean anterior chamber angle was significantly narrowed in patients with narrow-angle eyes compared with eyes with open-angle glaucoma. Study by Alonso et al (10) showed similar findings.

Our study found that the thickness of the lens in the patients with glaucoma was noted to be significantly increased ($p<0.00001$) in those with narrow angle compared with the eyes with open angle. George et al (11) also described that the mean lens thickness was greater in people with occludable angles compared to normal subjects.

The results of the current study indicate that MR gonioscopy has substantial potential as a non invasive technique for evaluating glaucoma despite its high cost compared with the costs of existing ophthalmologic examinations.

The three clinical features used to identify glaucoma patients, namely visual field defects, cupping of the optic discs and elevation of intraocular pressure may be seen in patients with neuro-ophthalmologic disorders as well. Additionally, glaucomas are such common illnesses that it does not preclude someone from having a second abnormality affecting the optic nerve.

On many occasions, the optic disc cupping can be a non specific finding and can occur in association with non glaucomatous conditions. Although the cupping in most neurologic diseases may look different than typical glaucomatous cupping, it is often noted that in the ophthalmologic community, these are more than occasionally confused. In such scenario, MRI can be helpful in assessment of the intraorbital optic nerve pathologies, viz. compressive lesions / optic nerve atrophy (12).

Unlike other well-established ophthalmological imaging methods, MRI provides true anatomic proportions independent of the optical and absorption characteristics of the ocular tissues.

One drawback with the studies using 1.5 T scanners is the limited SNR. Although 1.5 T MR scanners provide good contrast, spatial resolution, and detail, they offer inferior SNR when compared with ultra-high-field MRI.

Half-Fourier single-shot turbo spin echo (HASTE), enables one to take advantage of the long T2 relaxation time of fluid and involves a dramatically shortened imaging time. This sequence has been shown to be useful for MR cholangiopancreatography, urography, colonog raphy and fetal hydrography.

Tanitame et al described the usefulness of half-Fourier single shot turbo spin echo in imaging the eyeball. MR images obtained with a microscopy coil showed markedly higher spatial resolution and signal-to-noise ratios than MR images obtained with a conventional surface coil (13). High spatial- resolution MR imaging with a microscopy coil enables the use of half- Fourier single-shot imaging for evaluation of the anterior chamber configuration of the eyeballs. Half-Fourier single-shot imaging with use of multiple 180° pulses often requires operation at the specific absorption rate limits, particularly with 3-T MR units. However, the maximal specific absorption rate levels at MR gonioscopy performed with the 1.5-T MR unit were within the safety limits in all participants. Furthermore, the microscopy surface coil that they used was a commercially available insulated MR imaging receiver coil; no parts came in direct contact with the body so as to avoid local heating of the skin. These considerations suggested MR gonioscopy to be a safe technique for evaluating glaucoma.

To minimize partial volume averaging while achieving high spatial and temporal resolution for visualization of the anterior chamber configuration, we used HASTE MR imaging with 2.5-mm section thickness in this study. Other fast T2-weighted MR imaging techniques include balanced steady-state free precession sequences, such as balanced fast field echo—also known as true fast imaging with steady state precession (TrueFISP) & constructive interference in steady state (CISS) (14). Although the CISS may provide higher spatial and temporal resolution than does the HASTE technique, but it comes at the cost of increased time of acquisition. TrueFISP also may have higher spatial and temporal resolution than does the HASTE technique with other MR units that have higher gradient strength; on the basis of our anecdotal experience, this was probably not the case with our MR unit—hence, our choice of HASTE imaging for use in MR gonioscopy.

Although MR gonioscopic images have a lower spatial resolution than do US biomicroscopic images, MR gonioscopy can yield images sufficient for evaluation of the anterior chamber angle, peripheral curvature of the iris, and other anterior chamber configurations. Because US biomicroscopy involves direct patient contact via instillation of topical anaesthetic, placement of the eyecup, immersion of the eye in fluid, and transducer placement close to the cornea, there is a risk of infection or corneal abrasion (6, 15). Moreover, inadvertent posterior pressure on the eyecup during imaging can influence the angle configuration and may cause artificial narrowing of the angle. The noncontact nature of MR gonioscopy not only enhances patient comfort and safety but also makes it especially suitable for ocular biometry and assessment of the anterior chamber angle because there is no mechanical distortion of the tissue being imaged.

Eye movement artefacts are one of the most important issues in high-spatial- resolution MR gonioscopy, as is the case with other ophthalmologic techniques for glaucoma evaluation. When eye movement blurs the acquired image, the eye must be imaged again. In addition, MR gonioscopy requires patients to control their eye movement and fix their eye in one direction so that the central cross-sectional image of the anterior chamber region can be acquired correctly.

There were a few limitations to our study. First, because only the true axial images of the eyes at the level of optic nerve were evaluated, the assessment of the angle structures in other meridians was not done. This may have contributed to non visualisation of the iridotomy / trabeculoplasty status or false negatives if the angle was narrowed in a limited portion of the circumference. Second, because the MR gonioscopic images were obtained with only one MR unit and only one circular polarized array head coil, we do not know whether our findings are generalizable to other MR units and other coils. The high cost of the MRI may be a limiting factor for their use in routine clinical set-up or screening purposes.

CONCLUSION

In addition to assessment of the globe, MRI has advantage of evaluation of the entire visual pathway and aids in the differential diagnosis of the cases with atypical non glaucomatous optic nerve head cupping. The results of our study indicate that Half-Fourier single-shot turbo spin echo MR imaging with a circular polarized array head coil depicts the details of anterior chamber anatomy in patients with narrow- and open-angle glaucoma and that MR gonioscopy has the potential to be an alternative evaluation technique for individuals at risk for narrow-angle glaucoma.

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