ORIGINAL ARTICLES

Study on normal ophthalmic tissues among ocular volume and extraocular muscles structure measurement by HR-MRI

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Abstract

Objective: To measure the ocular volume and extraocular muscles of healthy people using the high-resolution magnetic resonance imaging (HR-MRI) technology, to provide parameters support for eye research, teaching and diagnosis.
Methods: The study collected 100 cases of normal subjects (200 eyes) from November 2012 to December 2013, including 50 males and 50 females, accepted line HR-orbital MRI, and image processing software was applied to morphology and statistical analysis. The extraocular muscles, muscle belly level horizontal diameter and maximum diameter vertical diameter were measured.
Results: The volume of the vitreous cavity (4.51 ± 0.26) cm^3 had no significant difference with the anatomic normal value (p = .148); The volumes of the ocular globe, the anterior chamber and the lens cavity were (5.05 ± 0.21) cm^3, (0.24 ± 0.26) cm^3, (0.23 ± 0.14) cm^3, with no statistic differences compared with those of the anatomic normal values. The extraocular muscles of normal Chinese were symmetrical on the two sides. The relationships of the short diameters of extraocular muscles in the maximum planes were: inferior rectus muscle (IR) > medial rectus muscle (MR) > superior rectus (SR) > lateral rectus muscle (LR). Those of the long diameters of extraocular muscles were: LR > MR > SR > IR.
Conclusions: MRI can be used for measuring ocular volume and sizes of extraocular muscles. Compared with the anatomic normal value, the sizes of extraocular muscles can also be assessed by the symmetry on the two sides and by observing the usual rule of extraocular muscles.

Key Words: HR-MRI, Normal ophthalmic tissues, Ocular volume, Extraocular muscles measurement

The emergency of high-resolution magnetic resonance imaging (HR-MRI) technology makes it possible for us to observe human body.[1] Although CT has been used to anatomize and biometrically examine the ocular tissues, the disadvantage of CT limits the accuracy and feasibility of its measurement, such as low tissue resolution, radiation artifacts and radiation damage.[2–4] MRI imaging is different from the density value of CT, which is the signal intensity value of different tissues. Because of the different forms, meridians and water contents of various tissues, MRI can not only show various tissue boundaries and location patterns, but also show the degree of lesions, such as fibrosis of tissue structure. So HR-MRI is an ideal way to study and examine ocular tissues.[5]

The use of MRI to study the normal human lacrimal gland structure by Yu WL et al.,[6] is of great significance for early detection and correct analysis of lacrimal gland le-

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sions. The researches on the application of HR-MRI to the eyes at home and abroad are mainly focused on the exploration of some ocular diseases, while the normal standard of ocular tissue structure is lacking. The HR-MRI technology was used in this study to measure ocular volume and extraocular muscle for 100 adult volunteers with normal eyes, and to explore its clinical significance.

1 Materials and method

1.1 Participants

A total of 100 normal adult volunteers (family members, friends and relatives from Department of Ophthalmology, The Third Affiliated Hospital, Inner Mongolia, China) from November 2012 to December 2013 were enrolled, including 50 males and 50 females, aged 18-75 years, with an average age of (38.25 ± 9.11) years. All volunteers should satisfy the following inclusion criteria: uncorrected visual acuity $\geq$ 1.0 during routine ophthalmology examination, eye position is positive, the eyeball protrusion is 12-14 mm, normal eye movement with no nystagmus. There are no ocular and systemic diseases of other orbital tissue morphology, such as congenital or acquired orbital facial deformity, no thyroid-related eye disease, no orbital inflammatory pseudotumor and, and systemic development is normal. Ocular volume and extraocular muscles of the 100 volunteers were measured. All subjects signed informed consent according to medical ethics requirements.

1.2 HR-MRI examination method

1.2.1 Equipment and scanning method

Siemens Magnetom Trivo Tim 3.0T superconducting MRI scanner was used in this study. Head coil for magnetic resonance imaging was performed in supine position. The head was placed in the line indiscriminately, left and right symmetry, adjusting the median sagittal brain position so that it coincided with the longitudinal axis of the coil. The oblique sagittal scan of the orbital transection, coronal and parallel optic nerve was performed. The transverse scan line was parallel to the auditory canal. The volunteers were warned to close their eyes during the scan.

1.2.2 MRI conventional scanning

T1W1 imaging of spin echo (SE) sequence: (1) Axial scan parameters: time of repetition (TR) 500 ms, time of echo (TE) 8.2 ms, field of view (FOV) 180 mm × 180 mm, layer thickness 2.5 mm, layer spacing 0 mm, flip angle (FLIP) 180°, acquisition matrix 260 × 213. (2) Coronal scan parameters: TR 600 ms, TE 8.2 ms, FOV 180 mm × l80 mm, layer thickness 3.0 mm, layer spacing 0 mm, FLIP 70°, acquisition matrix 260 × 213.

T2W1 imaging of SE sequence: (1) Axial scanning parameters: TR 6,000 ms, TE 94 ms, FOV 180 mm × l80 mm, layer thickness 2.5 mm, layer spacing 0 mm, FLIP 120°, acquisition matrix 320 × 288. (2) Coronal scan parameters: TR 4,000 ms, TE 84 ms, FOV 180 mm × 180 mm, layer thickness 3.0 mm, layer spacing 0 mm, FLIP 120°, acquisition matrix 384 × 346.

1.2.3 Imaging analysis and data processing

(1) Measurement of ocular volume. HR-MRI for three-dimensional imaging (T2-weighted images) was used, including transverse and sagittal. Clicked the left mouse button at the measurement area and outline the eyeball after 2.5-3.0 magnification. Computer software can automatically calculate the cross-sectional area based on the number and size of the pixels in the contour, and the area of each part is added to each layer and the thickness is multiplied to get the volume of the eyeball. The subjects were measured in supine, horizontal and sagittal position. The subjects were ordered to adjust their head positions and close eyes to reduce small muscle measurement error caused by traction. The examiner tried to be symmetrical when taking the imaging, scanning layer thickness 0.5 mm; field of vision 130 mm × l30 mm, acquisition time 410 s.

(2) Imaging analysis and data processing. The horizontal diameter and vertical diameter of the roughest surface of the extraocular muscles: the oblique coronal plane was perpendicular to the orbital axis of the volunteers in order to measure the extraocular muscles. The vertical diameter represents the distance between the uppermost edge and the lowermost edge of the muscle belly, and the horizontal diameter represents the distance between the innermost edge of the muscle belly and the outermost edge (see Figure 1). On the oblique coronal plane, we choose the most extensive layer of extraocular muscles, which is 3-6 mm back of the eyeball to the optic nerve. Generally, it is on the same level for the internal, external, superior, inferior rectus and superior oblique muscles. In this paper, the oblique coronal level of junction of optic nerve and ball wall was defined as the 0 level, and the plane was defined as the 1-5 layer respectively.[9]

The diagonal coronal plane scan thickness was 1.5 mm, and the diameter of extraocular muscles of 2-4 layers was measured, that is, the vertical diameter and horizontal diameter of medial rectus muscle (MR), lateral rectus muscle (LR), superior oblique muscle (SO), superior rectus muscle (SR) and rectus muscle (IR) posterior to the optic nerve and the posterior wall at 3 mm, 4.5 mm, 6 mm, which were measured 3 times, and the maximum average value was taken as the width of horizontal diameter and vertical diameter.

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The relationship between the length of the extraocular muscles and the short diameter of the extraocular muscles was compared.

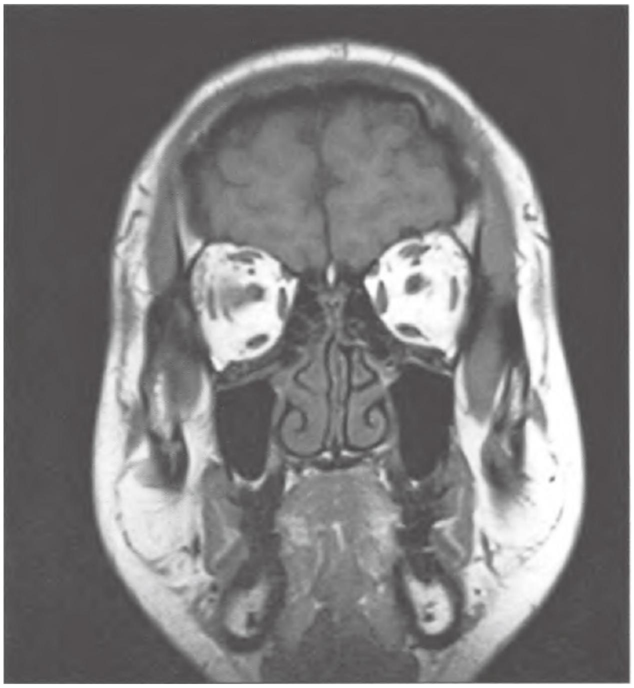

Figure 1: T2W1 imaging of orbital coronal plane

1.3 Statistical methods

Statistical analysis software SPSS16.0 was used for statistical processing. Measurement data were expressed as $\bar{x} \pm$ s. The independent sample *t*-test was used for the comparison of different genders and eyes. Bilateral $\alpha = 0.05$, $p \leq .05$ was considered statistically significant.

2 Results

2.1 Measurements of ocular volume and internal volume

There was no significant difference between the vitreous body volume of the subjects and the normal value of the ophthalmology.[10] The ocular volume was smaller than the normal value of ophthalmology, and the difference was statistically significant. The anterior chamber volume and lens volume were larger than the normal value of ophthalmometry, and the differences were statistically significant ($p < .05$, see Table 1).

2.2 Comparison between the ocular volume and internal volume values

The sum value of the ocular volume and the internal volume was (5.05 ± 0.21) cm^3 and (5.05 ± 0.47) cm^3, respectively, with no significant difference ($t = 0.879$, $p = .210$).

Table 1: Comparison between the ocular volume and internal volume with normal values (n = 200)

Project	Measurement ($\bar{x}$ ±s, cm^3)	Normal (cm^3)	*t*-value	*p*-value
Eyeball	5.05 ±0.21	6.50	-16.597	.000
Anterior chamber	0.24 ±0.26	0.21	8.958	.000
Lens	0.23 ±0.14	0.20	8.100	.000
Vitreous cavity	4.51 ±0.26	4.50	1.481	.155

2.3 Horizontal diameter and vertical diameter of extraocular muscle at the roughest level

The lateral extraocular muscles of the normal people were symmetrical. For the tested results, there were 91 cases of horizontal diameter < 0.5 mm on both sides of MR, LR, and vertical diameter < 0.5 mm on those of SR, IR and SO, accounting for 91%; and the number of cases with level ≥ 0.5 mm was 9, accounting for 9%. The maximum difference between the two sides was 0.7 mm. Measurement value difference between vertical diameter of MR, LR and the horizontal diameter of SR, IR, SO on both sides was < 0.5 mm in 85 cases, accounting for 85%, while ≥ 0.5 mm in 15 cases, accounting for 15%, the maximum difference on both sides was 1.1 mm. It can be seen in Table 2 and Figure 2, the extraocular muscles on both sides of the normal people were symmetrical, and the short diameters of the extraocular muscles in the largest diameter line were: IR > MR > SR > LR, long diameter: LR > MR > SR > IR.

3 Discussion

MRI carries the characteristics of soft tissue resolution, arbitrary section imaging, no bony artifact and no radiation though ultrasound, *X*-ray, CT and MRI can clearly show the orbital structure and make quantitative analysis. MRI has a distinct advantage over CT in various sections that provide orbital sections, especially for the examination of ocular lesions.[11] Human tissue variation and pathological changes from multiple dimensions can be observed in three dimensions by HR-MRI medical images.

Table 2: Measurement of the extraocular muscle line of the MRI oblique coronal maximum cross-section ($\bar{x}$ ± s, mm)

Measure diameter	Eye	Measurement	*t*-value	*p*-value
MR vertical	left	8.94 ±1.50	-0.970	.33
	right	9.13 ±1.26		
MR horizon	left	3.74 ±0.48	-0.100	.20
	right	3.66 ±0.40		
LR vertical	left	10.92 ±1.35	-0.100	.11
	right	10.44 ±1.04		
LR horizon	left	3.28 ±0.39	-1.396	.16
	right	3.36 ±0.42		
IR vertical	left	4.51 ±0.68	-1.111	.27
	right	4.62 ±0.72		
IR horizon	left	7.90 ±1.04	-0.100	.52
	right	7.79 ±1.25		
SR vertical	left	3.48 ±0.64	-1.422	.16
	right	3.60 ±0.55		
SR horizon	left	9.74 ±1.56	-0.100	.25
	right	9.51 ±1.22		
SO vertical	Left	3.22 ±0.31	-1.571	.12
	right	3.32 ±0.50		
So horizon	left	5.20 ±1.10	-1.697	.09
	right	5.48 ±1.23		

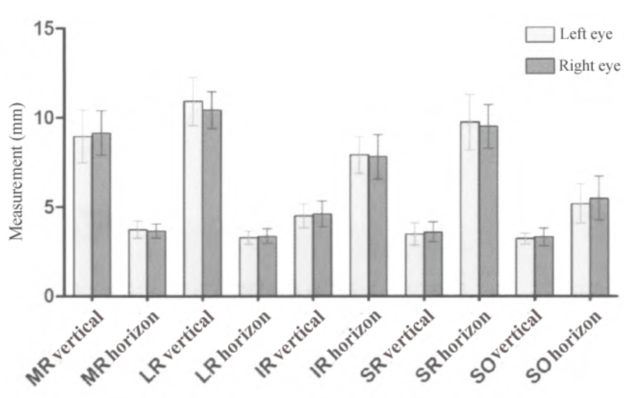

Figure 2: Column of the extraocular muscle line of the MRI oblique coronal maximum cross-section

Accurate measurement of ocular volume is of great significance in clinical practice. If silicone oil or gas is injected into the vitreous cavity of the retina, we can predict the prognosis of the operation through the preoperative and postoperative measurement of the vitreous cavity. Ge YR et al.[12] found that the ocular volume and vitreous volume increased with the applications of CT measurement after silicone oil filled eye surgery. According to MRI imaging principle, accurate measurement of the vitreous cavity volume can provide some references for vitreous surgery. In this paper, the measured value of the ocular volume was in agreement with the data reported by Chen Y et al.,[13] who used MRI for the measurement of ocular volume. Many ocular volume data are derived from isolated eyeballs. As a result of histomorphological changes, some changes in biochemical substances affect the accuracy of the data. There is a difference between the data of the ocular volume measured by HR-MRI and the reference values in the textbook, but there is no statistically significant difference in the data of the vitreous volume. The difference between the total ocular volume and the sum of internal volumes was not statistically significant, which is reasonable, indicating the possibility of ocular measurement in vivo, and provides a reference.

The data of extraocular muscle measured in this paper are consistent with the data of Li RL et al.,[9] who used MRI for the study of extraocular muscles of normal and non-common strabismus patients. Ren YL et al.[14] used eyeball dynamic MRI technology to measure the change of the cross sectional area of 4 rectus muscles in normal people in the original position and the eyeball's horizontal and vertical rotation. It provides a reference for MRI diagnosis and surgical treatment of extraocular myopathy. Through the study of normal extraocular muscle cross-section, we can provide reference for the measurement of extraocular muscle disease. In short, the measurement of eyeball biological data of MRI will have broad application prospects in ophthalmology field.

Conflicts of Interest Disclosure

The authors have no conflicts of interest related to this article.

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