(11)

The use of dynamic magnetic resonance in the diagnosis of ocular motility disorders

Zastosowanie dynamicznego rezonansu magnetycznego w diagnostyce zaburzeń ruchomości gałek ocznych

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Summary: Dynamic Magnetic Resonance (dMRI) of the extraocular muscles is based on performing a number of short sequences, while the patient fixates consecutive points placed in different positions of gaze.
Purpose: To check the relation between dMRI findings and the results of clinical examination in patients with various types of strabismus.
Materials and methods: We have selected three patients with lateral rectus palsy, superior rectus palsy and inferior rectus restriction from the group, in which we have performed dMRI. We have taken measures of the affected muscles shape, sectional area and volume. The results were related with the clinical examination.
Results: The measurements obtained with use of dMRI reflect the actual state of the affected muscle as seen on the Hess screen. The limitation of the muscles action is represented by a lack of increase in the sectional area and volume in respective gaze intervals. The restriction of the muscle affects its shape by pulling it towards the place of entrapment.
Conclusions: Data acquired by means of dMRI correspond to the clinical findings and allow a quantitative analysis of the degree of muscle weakness. Defining the extent of the morphological changes in extraocular muscles, related with long-lasting paralysis, let us make an informed decision regarding further treatment.
Słowa kluczowe: dynamiczny rezonans magnetyczny, ruchomość gałek ocznych, mięśnie gałkoruchowe.
Key words: dynamic magnetic resonance, ocular motility, extraocular muscles.

Introduction

Dynamic Magnetic Resonance (dMRI) of the extraocular muscles (EOM) is based on performing a number of short sequences, while the patient fixates consecutive points placed in different positions of gaze. It finds its application in a congenital, paralytic and post-traumatic disorders (1-3) of extraocular muscles by demonstrating their functional status. It is also a useful tool that allows us to “look into” the extraocular muscles function and pathophysiology while they act.

Methods

The protocol for dMRI was standardized for both control and studied subjects. The 1.5T scanner (Avanto, Siemens) with standard head coil was used. The patient was carefully instructed before the examination of how to react to the commands issued via the loudspeaker. The plastic dome (Hejna Co.) that fitted the scanner tube was prepared in order to serve as a board for fixation targets. After immobilizing the patient’s head by means of a plastic collar and placing the dome overhead the examined eye was covered with a patch. The aim of patching the examined eye and not the other was not to let the fixation limit eye’s rotations. In this manner the other eye was the fixing one and the examined eye made conjugate movements freely. By covering one of the eyes we have also eliminated convergence (4) which might have influenced our results.

Thirteen fixation targets were marked on the transparent foil in 10° intervals. Numbered marks were placed in 10°-30° abduction, 10°-30° adduction and vertical ductio as well 10°-30°. Due to the fact that the action of both inferior and superior rectus muscles is greatest in around 20° abduction the vertical fixation targets were shifted 20° in a respective direction. The foil was sticked to the surface of the plastic dome with number 1 as primary position in front of the fixing eye and the vertical fixation targets in 20°adduction. In that way the examined eye rotated vertically in 20° abduction. The short, dynamic T2 sequences were performed in coronal plane and calibrated as so the main axis of the visualized field was shifted 23° temporally from the center, in order to coincide with the horizontal and vertical rec-

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tus muscle planes. Each sequence lasted 13 seconds per gaze position.

In our opinion it was the best duration time, that gave us still a high quality image and reduced the possibility of motion artifacts caused by blinking. In the control group both eyes were examined. In the studied group the sound eye could not be a subject to a comparison due to inability to fixate all targets with the affected eye. The overactivity of contralateral agonists could as well contribute to false interpretation of obtained measurements. In the studied group the dynamic sequence was repeated 7 times for each patient while the gaze positions varied depending on which muscle was to be visualized. In the control group, in order to analyze all four muscles, we had to perform the sequence 13 times per subject. Examination period in neither of the cases exceeded the time slot allocated for the standard orbital MRI (30 minutes).

The acquired images were analyzed with use of DicomWorks 1.3.5 and ImageJ 1.38x software on a freeware licence. The measurements of affected muscles shape, sectional area and volume were obtained by the same researcher. The standardized protocol for those measurements was introduced to avoid any bias. Twelve slices representing the same anatomical level in each patient were picked for further analyses. The images were transformed to 60 units of gray value and each muscle was circled with an automatic wound tool. The changes in the measured parameters were noted along the field of action of the examined muscle.

We have selected three patients with lateral rectus palsy, superior rectus palsy and inferior rectus restriction from the group that we have examined with dMRI. We have related the results with the clinical examination including ocular motility test performed on the Hess screen. The results were also compared with the reference group. It consisted of 5 volunteers (10 orbits) with mean age of 38 ± 8.3 years and without any ocular motility abnormalities.

Results

Patient 1.

Twenty-nine-year old male was complaining of diplopia due to trauma to the right orbit. Throughout examination (including CT scan), right orbital floor fracture was revealed. The orthoptic findings were: orthophoria in primary position, right hypotropia in upgaze (12Δ), right hypertropia in downgaze (8Δ). The above pattern of ocular motility impairment was suggestive of an inferior rectus restriction (somewhere in the middle of the muscles length) (Fig. 1).

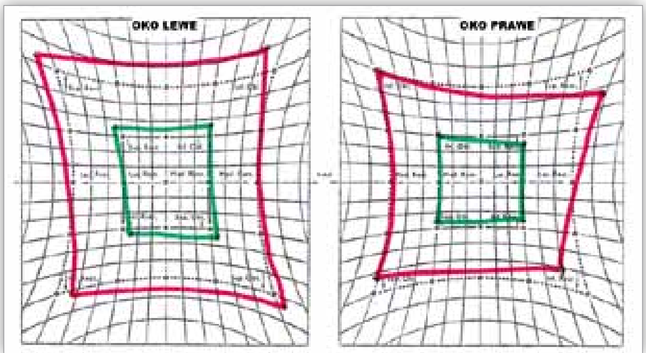
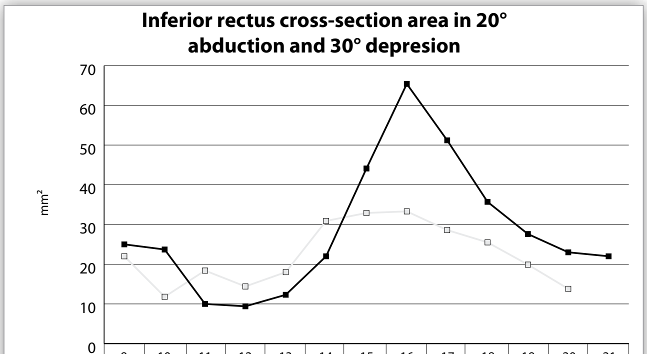


Fig. 1. Hess' screen chart of Patient No1.
Ryc. 1. Wykres badania na ekranie Hessa pacjenta nr 1.

The performed dMRI revealed a significant increase of inferior rectus cross-section area between the 15th and 17th slice, what gives 28-32mm from the anterior pole of the globe, thus identifying the exact localization of the inferior rectus restriction area (Fig. 2, 3).



	9	10	11	12	13	14	15	16	17	18	19	20	21
PATIENT 1	25	23	10,0	9,4	12,3	22,0	44,1	65,4	51,2	35,7	27,6	23,0	22,0
REFERENCE	22,0	11,8	18,4	14,4	18,0	30,9	32,9	33,3	28,6	25,5	19,9	13,8	

Fig. 2. Patient's No 1 inferior rectus muscle cross-section area in 20° abduction and 30°depression.
Ryc. 2. Pole przekroju mięśnia prostego dolnego pacjenta nr 1 w 20° odwiedzeniu i 30° opuszczeniu gałki ocznej.

Fig. 3. Patient's No 1 MRI frontal cross-section of the right orbit in 20° abduction and 30° depression in comparison with a reference case.
Ryc. 3. Obraz RM prawego oczodołu w przekroju czołowym pacjenta nr 1 w 20° odwiedzeniu i 30° opuszczeniu gałki ocznej w porównaniu z przypadkiem z grupy kontrolnej.

Additionally we haven't noted gaze-dependent shift of the muscles maximal cross-section area. It usually shifts posteriorly when muscle contracts and anteriorly with its relaxation (1,5,6). In our opinion this may be due muscles inability to contract nor relax properly. Acquired images have revealed that the inferior rectus is not directly entrapped in the fracture fissure. Nevertheless the surrounding tissues pull its body downwards, especially in depression, what is probably the reason for the 8Δ deviation in downagaze.

Patient 2.

Forty-six-year old female referred with severe vertical diplopia that has followed extraction of the orbital tumor (extrapleural solitary fibrous tumor). The surgery occurred to be successful – no remnants found on MRI, but resulted in moderate ptosis and hypotropia of the right eye (22Δ) greatest in abducted upgaze. On the basis of full orthoptic examination we have diagnosed superior branch oculomotor palsy (Fig. 4).

In this patient the superior rectus palsy was quite recent, thus the muscles volume is similar to the reference – showing no signs of atrophy. The cross-section areas in 20° abduction are comparable as well, but there is no increase in cross--section area on attempted elevation, what is a visible sign of muscles palsy (2,4) (Fig. 5).

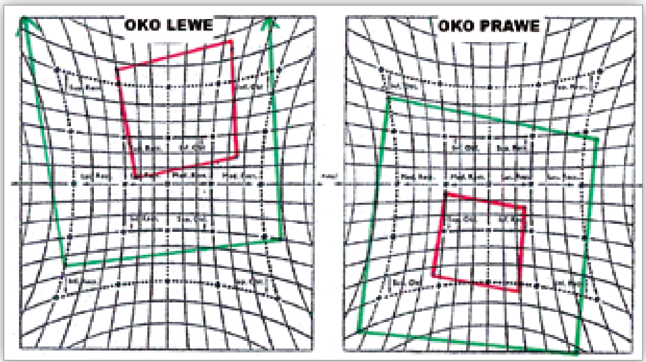
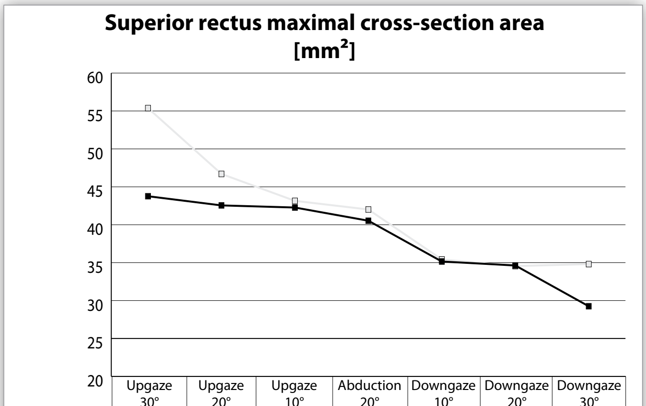


Fig. 4. Hess' screen chart of Patient No 2.
Ryc. 4. Wykres badania na ekranie Hessa pacjentki nr 2.



	Upgaze 30°	Upgaze 20°	Upgaze 10°	Abduction 20°	Downgaze 10°	Downgaze 20°	Downgaze 30°
PATIENT 2	43,76	42,55	42,27	40,53	35,15	34,63	29,25
REFERENCE	55,38	46,7	43,15	42,01	35,42	34,55	34,81

Fig. 5. Patient's No 2 superior rectus muscle maximal cross-section in different gaze positions.
Ryc. 5. Pole maksymalnego przekroju mięśnia prostego dolnego pacjentki nr 2 w poszczególnych kierunkach spojrzenia.

We have also found an increased superior rectus circularity suggesting a diminished muscle tonus.

Patient 3.

Fifty years old male referred due to diplopia and marked right ET. The symptoms appeared after head trauma one year prior the referral. Full examination revealed ET (36Δ) increasing in abduction. Those and other findings were suggestive of right VI-th nerve palsy (Fig. 6).

In a long-standing VI-th nerve palsy the overacting ipsilateral medial rectus may not allow us to properly estimate the remaining degree of lateral rectus function. However by means of dRMI we can observe whether there is a change of lateral rectus cross-section area on attempted abduction. In this case despite the lower volume – possibly due to muscles atrophy (1,4), we could find, lower than in reference, but still marked increase of maximal cross-section area on abduction, what gives us the idea of muscles capability to contract. Increased muscles circularity, as we think, represents diminished muscle tonus. As can

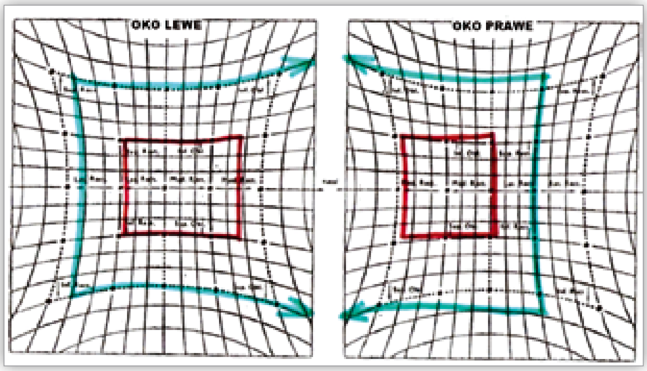
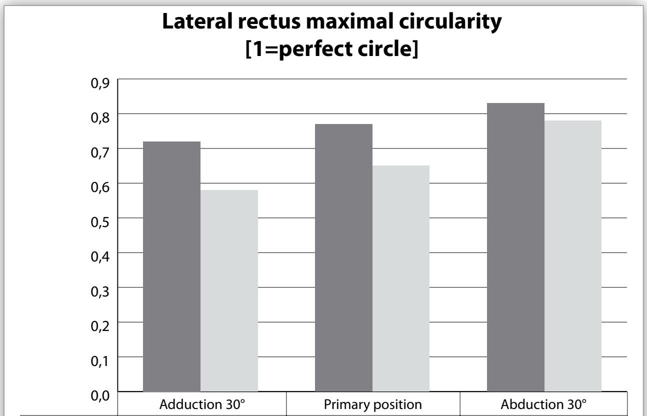


Fig. 6. Hess' screen chart of Patient No 3.
Ryc. 6. Wykres badania na ekranie Hessa pacjenta nr 3.



	Adduction 30°	Primary position	Abduction 30°
PATIENT 3	0,72	0,77	0,83
REFERENCE	0,58	0,65	0,78

Fig. 7. Patient's No 3 lateral rectus muscle maximal circularity in the primary position, 30° adduction and 30° abduction.
Ryc. 7. Maksymalna kolistość mięśnia prostego bocznego pacjenta nr 3 w pozycji pierwotnej, 30° przywiedzeniu i 30° odwiedzeniu gałki ocznej.

be observed there is a decrease of circularity in adduction (both in patient 3 and reference) (Fig. 7).

The cause of this fact is that the muscle is being stretched and flattened, on the surface of the globe, when medial rectus contracts.

Discussion

Various methods were implemented in order to visualize the morphology and anatomy of extraocular muscles, but in order to observe their function there is a need of a tool satisfying certain requirements. The previously used computer tomography (7) and echography (8) were of minor use mostly due to intensive radiation in the former and low resolution in the latter. dMRI is free from these disadvantages. In recent years several studies on EOMs pathophysiology were made with use of MRI showing it might be useful, not only in visualizing static state (9) of the oculomotor aparatus, but showing it's action as well (4). A study by Tian et al. (10) was an inspiration for this paper. The group from Karolinska Institute obtained images that allowed them to measure basic parameters of EOMs along different gaze positions. Their study focused on normal subjects and establishing normal values for certain EOM parameters. Their intention was to develop an orbital MRI examination method which could be performed as a routine clinical examination.

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Our initial study have shown that it's possible. We have tried to use similar methodology, despite the fact that we have found that there are many variables (ie. sequence parameters, patient positioning, way of obtaining measures of the EOMs) that might influence the final result. The EOM parameters measured in the reference group were similar to those found by Tian et al. (10) This finding encouraged us to perform dMRI in patients with ocular motility impairment.

Our study focuses on three parameters: maximal cross-section, volume and circularity. The rationale for assessing maximal cross-section area of the palsied muscle in its field of action, was that in such case, it should not increase or the increase should be lower than in reference. This is the case in patient 2 and 3. Similar study was performed by Bloom et al. (2) in which they reported evidence for reduced coronal muscle cross-section in patients with III[rd] and VI[th] nerve palsies. Demer et al. (4) have analyzed patients with rectus muscle palsy and as well noted the reduction of cross-section area of a paralytic muscle.

The volume measurements should identify muscles morphological changes such as atrophy or hypertrophy (11). In patient 3 the long-standing lateral rectus hypofunction had led to denervation hypoplasia and so decrease in volume. Demer et al. (2) have postulated the same mechanism in the study on chronic IV[th] nerve palsy.

Circularity is a parameter giving us the idea of muscle shape. The normal EOM visualized in the MRI looks like a flattened ellipse. It becomes flatter when it is stretched on an eye ball and more circular when it contracts. What we have found to be useful, was measuring muscles circularity when it is in its position of rest. The palsied muscle appears to be more circular in such conditions than a normal one. We think that the diminished tonus, related with impaired innervation, is responsible for this finding.

Analysis of inferior rectus entrapped in the course of orbital floor fracture by means of MRI were performed by few authors. Totsuka and Koide (3) have found that the restriction of inferior rectus action is sometimes due to involvement of the surrounding tissue and not the muscle itself. Nevertheless, as we can see in patient 1, the muscle is pulled down by the soft tissue and the shape and cross-section area are disturbed. Our further studies focus on trying to quantify the above findings and relate the exact amount of deviation with the measured parameters. To do so we are currently gathering a larger group of patients with peripheral nerve palsy.

Conclusion

Data acquired by means of dMRI correspond to the clinical findings and allow a throughout analysis of the muscle function. Defining the extent of the morphological changes in the extraocular muscles, related with recent or long-lasting paralysis, let us make an informed decision regarding further treatment. Further study is needed to make the dMRI findings quantifiable and more suitable for clinical use.

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