VARIATIONS OF THE INSERTIONS OF HORIZONTAL EXTRAOCULAR MUSCLES

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ABSTRACT

Introduction: Determination of the scope of surgical interventions, either repositioning or myectomies of the horizontal rectus extraocular muscles is based on calculations that do not take into account the distance of the insertion of the respective muscle.

Aim: The aim of this article is to assess the variations of insertion of the horizontal rectus extraocular muscles.

Materials and Methods: The research includes 63 children (126 eyes) with an average age of 4 years and 4 months (the youngest is 1 year and 2 months old; and the oldest is 16 years old) with comitant horizontal strabismus, all of whom underwent surgery for a period of 2 years (2016 – 2018). All patients have gone through a thorough ophthalmic examination, including determination of cycloplegic refraction. Measurement was performed intraoperatively.

Conclusion: It was determined that the median distance between the limbus and the insertion regarding the medial rectus muscle was 5.11 mm (ranging from 4.5 mm to 7 mm) and regarding the lateral rectus muscles —
6.29 mm (ranging from 5 mm to 8 mm). The main finding shows that the insertion of the horizontal rectus extraocular muscles varies significantly, which requires intraoperative refinement of the scope of surgical intervention to achieve maximum therapeutic result.

**Keywords:** insertion, comitant strabismus, resection, retroposition

**INTRODUCTION**

Determination of the scope of surgical interventions of the horizontal rectus extraocular muscles, to either strengthen the muscle action (recessions, retropositions) or to weaken it (myectomies) is based on calculations that do not take into account the distance of the insertion of the respective muscle. The traditional perception of a maximum recession of 4.5-5mm is derived from the classic study of Fuchs, according to which the medial rectus muscle (MRMed) inserts at 5.5 mm from the corneoscleral limbus. More recent studies performed in autopsies and patients with congenital esotropia show significant individual variations within this range as very often the MRMd inserts closer than 5.5 mm (1,2,3,4). In a series of strabismus patients, Kushner found large variations in the distance between the muscle insertions and the equator, as well as between the limbus and the equator (5). Most formulas for surgical intervention are given as mm muscle displacement relative to the old insertion or to the limbus, with a maximum value not to be exceeded in order not to disturb the function of the muscle. Typically, the equator of the bulbus is the landmark that serves as boundary. Kushner notes that in some patients a recession of no more than 3.5 mm places the muscle on the equator, and in other cases with a recession of 8.5 mm, the equator is not reached yet. In another study, Kushner finds a statistically significant inverse correlation between the antero-posterior axis of the eye and the effect of the operation (Δ for mm recession), and considers that the axial length of the eye is one of the factors that, if included in the dosing formula, would reduce by 25% the variability of the postoperative outcome (6).

The same author calculates the distance from the limbus to the equator for a given axial length of the bulbus, based on a 4-year echobiometry study of 180 strabismus cases (5). In order to help strabismus surgeons who did not have ultrasound equipment, Kushner creates an algorithm of the antero-posterior axis in relation to a given age and refractive state. Based on an analysis of 28 recessions made behind the equator, Kushner et al. state that not the equator itself, but a position up to 1.5 mm behind the equator is the safe maximum recession that does not lead to disturbance of the function of the MRMd and the risk of postoperative hypercorrections as far as pure mechanical factors are considered, is lower. With a patient who has had the MRMd of one eye recessed 2 mm behind the equator, and of the other eye - on the equator, the probability of developing consequent exotropia is greater than in a patient in whom both MRMd are recessed 1 mm behind the equator, despite the equal cumulative shifting.

With the increased tendency of strabismus surgeons to perform recessions of the rectus muscles more than the conventional maximum amounts, the necessity for paying strict attention to the manner in which the limbus-to-insertion site distance is measured and the appreciation of accurate normal values for these distances becomes a matter of practical importance to avoid excessive weakening of muscle action. The maximum lateral rectus muscle (MRLat) recession traditionally has been 7 mm. Although a few ophthalmic
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surgeons for years have recessed the lateral rectus muscle 8 to 10 mm in recent years more ophthalmologists have begun to perform these large recessions commonly for sizeable exotropias, even in children (7,8,9,10). Recessions of the medial rectus muscle more than the conventional amounts of 5 to 5.5 mm also are being performed more frequently, particularly for large angle childhood esotropia (11,12,13). In performing full or extra-large recessions of the medial rectus muscle, several authors recommend measuring the recession distance from the limbus rather than from the original insertion site because of its potential for variation (confirmed in this study) (4,13). Recessions of the vertical rectus muscles more than the ordinary maximum amount are done regularly now by ophthalmic surgeons. In thyroid ophthalmopathy, the inferior rectus muscle, normally recessed up to 5 mm, may be recessed 6 mm or more. In dissociated vertical divergence, recessions of the superior rectus muscle 8 mm or more, rather than the usual limit of 5 mm, have been found effective by some strabismus surgeons (14,15).

Another situation in which the surgeon needs knowledge of the exact location of the insertion site is in reoperation for overcorrection after recession. When an advancement is carried out, an important point of reference for the surgeon would be the original insertion line. Transposition operations in which insertions of horizontal and vertical rectus muscles are moved to improve horizontal and vertical deviations have represented a notable advance in strabismus surgery. Much of the credit for presenting and popularizing these concepts belongs to Knapp (16,17). Transpositions of rectus muscle insertions nowadays are done regularly by strabismus surgeons. These procedures have been effective in certain cases of A-V patterns, small concomitant vertical imbalances where no dysfunction of any specific vertically acting muscle is apparent, double elevator or depressor paralysis, third and sixth cranial nerve paralysis, residual horizontal deviation after maximum horizontal muscle surgery, and Duane’s syndrome. Certain strabismus operations require a thorough knowledge of the anatomy of rectus muscle insertions. Earlier anatomical studies were based on a small sample size and were obtained upon normal adult autopsy eyes of adult patients. Anatomical relationships of rectus muscle insertions and limbus were illustrated by Apt as demonstrated on Fig.1 (1). In this study we present the results of intraoperative

Fig. 1. Anatomical relationships of rectus muscle insertions and limbus (Apt) (1)
 measurement of the limbus–insertion distance of horizontal extraocular muscles in 126 eyes of pediatric patients, who underwent strabismus surgery.

**AIM**

The purpose of the study is to assess the variations of insertion of the horizontal rectus extraocular muscles of children with comitant strabismus.

**MATERIALS AND METHODS**

All patients have gone through a thorough ophthalmic examination including: assessment of visual acuity (with and without correction) for children in verbal age and fixation for all of those in preverbal age; determination of cycloplegic refraction; orthoptics and ocular motility assessment; biomicroscopy and ophthalmoscopy. Measurement of the limbus – insertion distance of horizontal extraocular muscles was performed intraoperatively, as shown by (Fig. 2).

The obtained results were processed using specialized software SPSS IBM v 23.0. In the interpretation, a critical level of significance p = 0.05 was chosen. A descriptive analysis was carried out. Depending on the distribution of the data, the mean or median, as well as the standard deviation, were taken respectively. Through One sample t-test and Wilcoxon signed rank test the data in each group of patients was compared with the established norms according to the classic study of Fuchs.

**RESULTS**

The research includes 63 children (37 males and 26 females) with an average age of 4 years and 4 months (the youngest is 1y and 2m old; and the oldest is 16y old) with comitant horizontal strabismus, all of whom underwent surgery for a period of 2 years (2016 – 2018).

Fig. 2. Measurement of the limbus – insertion distance of horizontal extraocular muscles in 126 eyes of pediatric patients, who underwent strabismus surgery.
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All patients are divided into four groups (Table 1), depending on the type of deviation and the type of surgical intervention performed. The table shows that two-thirds of all children are operated on due to convergent strabismus. Children with esotropia are additionally divided into two subgroups - congenital esotropia and other types of esotropia. Patients with exotropia are divided into patients with convergence insufficiency and patients with preserved convergence. Patients with infantile esotropia (nearly 40% of all children) are the most numerous. The mean age of surgical intervention (recession of MRMed of both eyes) in this group is 2y 5m, with males prevailing (68% of all patients operated on due to infantile esotropia). Variations in the MRMed insertion distance are between 4.5 mm and 7 mm. The average insertion distance is 6.29 mm.

Other types of esotropia are observed in a total of 17 patients (27% of all operated children) of mean age 5y 6m. Both eyes of 11 boys and 6 girls are operated (recession of MRMed of both eyes), with variations in the distance of insertion measured between 4 mm and 6.25 mm. The average insertion distance is 5.04 mm.

With exotropia and convergence insufficiency are two patients - a boy of 2y 8m and a girl of 6 years. A myectomy of the MRMed of both eyes is performed with the measured distance being 6 mm and 6.75 mm, respectively. The mean insertion distance of the MRMed is 5.11 mm (ranges from 4 mm to 7 mm); and the MRLat - 6.29 mm (ranging from 5 mm to 8 mm).

DISCUSSION

In three of the four groups of patients a statistically significant difference was found compared to the traditional values adopted.
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with respect to the distance of the insertions of the horizontal rectus muscles from the corneoscleral limbus. In the group of patients with exotropia and convergence insufficiency, the small number of patients does not allow statistical analysis. In Table 2 the mean values of the insertion distance of the respective muscles are presented according to the different authors. The table shows that our results do not match the values obtained in previous studies.

The patients with infantile esotropia (nearly 40% of all children) are the biggest group. Infantile esotropia occurs during the first 6 months of life. This group includes several types, such as: neonatal small angle esotropia, nonaccommodative infantile esotropia, Ciancia syndrome and congenital esotropia (18).

Other types of esotropia are observed in a total of 17 patients (27% of all operated children) of mean age 5y and 6m. This group also includes several types, such as: accommodative esotropia, nonaccommodative esotropia, cyclic and sensory esotropias. They often have an intermittent onset, which also explains the older average age of surgical intervention in this group.

The reasons behind the reported variations are discussed but they are not influenced by the age and gender of the patients (19,20,21). The relationship of the insertion variability to the postoperative outcome has not been demonstrated but constitutes an additional possibility of improving surgical interventions (22).

CONCLUSION

Due to the widespread trend amongst surgeons, for recessions of the rectus muscles in a volume larger than the classic maximum, particular attention is needed in measuring the distance of the insertion of the respective muscle and the assessment of possible deviations from traditional values in order to avoid excessive weakening of the corresponding muscle. The exact localization of the insertion could also be beneficial in case of reoperation due to excessive correction after a recession. The variability of the insertion

<table>
<thead>
<tr>
<th>Number of Eyes</th>
<th>MRMed mm</th>
<th>MRLat mm</th>
</tr>
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<tbody>
<tr>
<td>Fuchs (1884)</td>
<td>31</td>
<td>5.5</td>
</tr>
<tr>
<td>Weiss (1897)</td>
<td>5</td>
<td>5.05</td>
</tr>
<tr>
<td>Howe (1902)</td>
<td>21</td>
<td>5.7</td>
</tr>
<tr>
<td>Gat (1947)</td>
<td>80</td>
<td>5.4</td>
</tr>
<tr>
<td>Apt (1980)</td>
<td>100</td>
<td>5.3</td>
</tr>
<tr>
<td>Present study</td>
<td>126</td>
<td>5.11</td>
</tr>
</tbody>
</table>

Table 2. Presentation of the mean values of the distance between the corneal limbus and the middle of the insertion of the respective muscle (it must be taken into account that all previous studies, except for the present, were performed on autopsies of elderly patients)
Високата средна възраст при оперативната интервенция в Те често имат интермитентно начало, което обяснява и по-неакомодативна есотропия, циклична и сензорна есотропия. Към тях се отнасят няколко типа: акомодативна есотропия, интраоперативната интервенция с цел постигане на максимален терапевтичен резултат не е доказано, но представлява допълнителна възможност за прецизиране на хирургичната операция. Отношението на вариабилността на инсерциите към отстоянието на съответния мускул според различните автори. От таблицата е видно, че нашите резултати не съвпадат със съответните стойности, получени при предишни изследвания.

Най-голям брой са пациентите с инфантилна есотропия (близо 40% от всички деца). Инфантилната есотропия настъпва през първите 6 месеца от живота. Тази група включва няколко вида, като най-често това са: неонатална есотропия с малък отклоняване, акомодативна есотропия и конвергентна есотропия. Средната възраст 5 г. и 6 м. Други видове есотропия се наблюдаваха при общо 17 пациенти (27% от всички оперирани деца) на средна възраст 6 г. Тази група включва няколко видове есотропия с голям брой съвпад с класически възприетите максимуми, е необходимо особено внимание при измерването на отстоянието на инсерцията на съответния мускул и оценката на възможна дисфункция на мускула. Отношението на вариабилността на инсерцията към отстоянието на съответния мускул показва изключително широки граници и представлява фактор, който може да бъде използван за индивидуалното прецизиране на обема на хирургическата интервенция в хоризонталния аспект (22).

ЗАКЛЮЧЕНИЕ

Поради широкоразпространената тенденция срещу наддълбоко корекция на рефракцията на очите мускули в обем, по-голям по отношение на хоризонталните пръчки, щото се наблюдава при около 70% от всички пациенти. Ето защо е необходимо особено внимание при измерването на отстоянието на инсерцията на съответния мускул и оценката на възможна дисфункция на мускула. Точната локализация на инсерцията би могла да бъде използвана при евентуална реоперация при прекомерна корекция след реция. Вариабилността на отстоянието на инсерцията на съответния мускул показва изключително широки граници и представлява фактор, който може да бъде използван за индивидуалното прецизиране на обема на хирургическата интервенция в хоризонталния аспект (22).

distance of the respective muscle exhibits extremely wide limits and is a factor that can be used for the intraoperative refinement of the volume of the surgical intervention in order to achieve the maximum therapeutic outcome.

REFERENCES