BJO Online First, published on January 12, 2012 as 10.1136/bjophthalmol-2011-300632

Extraocular muscle insertion positions and outcomes of strabismus surgery: correlation analysis and anatomical comparison of Western and Chinese populations

Yu-Hung Lai,[1,2,3] Wen-Chuan Wu,[1,3] Hwei-Zu Wang,[1,3] Hsin-Tien Hsu[4]

[1]Department of Ophthalmology, Kaohsiung Medical University Hospital, Kaohsiung Medical University, Kaohsiung, Taiwan
[2]Graduate Institute of Medicine, College of Medicine, Kaohsiung Medical University, Kaohsiung, Taiwan
[3]Department of Ophthalmology, School of Medicine, College of Medicine, Kaohsiung Medical University, Kaohsiung, Taiwan
[4]School of Nursing, College of Nursing, Kaohsiung Medical University, Kaohsiung, Taiwan

Correspondence to
Dr Hsin-Tien Hsu, 100 Zih-You 1st Rd, Kaohsiung, 807, Taiwan; hthsu@kmu.edu.tw

Accepted 7 December 2011

ABSTRACT

Background/aims To compare the insertion locations of extraocular muscles between Taiwanese (Han Chinese) and Western populations and to determine whether anatomical differences warrant different surgical guidelines.
Methods Insertion locations were compared between a Taiwanese population of subjects who had received surgical treatment for strabismus and a control group who had not. Insertion locations and surgical outcomes in the strabismus group were also compared with those reported in other countries.
Results In Taiwanese subjects, extraocular muscle insertion locations were not significantly different between strabismus subjects and controls. However, the distances from the insertion location to the limbus of the inferior rectus, lateral rectus and superior rectus were significantly shorter in the Taiwanese subjects than in Western populations.
Conclusion Extraocular muscle insertion locations for the Taiwanese population in this study significantly differed from those reported in studies of Western populations. Therefore, surgical guidelines for performing lateral rectus recession to treat exotropia in Western populations may be inappropriate for Taiwanese and other Asian populations.

INTRODUCTION

Strabismus surgery is typically performed to strengthen or weaken the extraocular muscles (EOMs). The gross anatomy of the EOMs is well established.[1] Students are taught that the distances from the anterior limbus to the midpoint of the insertion locations for the medial rectus (MR), inferior rectus (IR), lateral rectus (LR) and superior rectus (SR) muscles are 5.3, 6.8, 6.9 and 7.9 mm, respectively.[1] The insertion location is known to vary, and we have observed that the EOM insertion locations in strabismus patients in Taiwan are more anterior than those reported in studies of Western populations. Therefore, the goal of this study was to investigate whether: (1) EOM insertion locations differ between subjects with and without strabismus in a Taiwanese (Han Chinese) population, (2) EOM insertion locations in the Taiwanese population differ from those in Western countries and, if so, (3) applying surgical guidelines developed for Western populations results in undesirable outcomes in Taiwanese patients.

METHODS

This retrospective study of patient medical records was approved by the Institutional Review Board of Kaohsiung Medical University. Data sets were compared between a strabismus group and a control group. The strabismus group comprised all consecutive patients who underwent an initial strabismus procedure performed by one of the authors (Y-HL) during 2005–2008. Patients were excluded if they had a history of congenital cranial dysinnervation syndrome, cerebral palsy, neurological disease, acquired strabismus such as that associated with cranial nerve palsy or thyroid orbitopathy. Patients who had received adjustable sutures were also excluded. Deviations were measured using the plastic prism and cover–uncover test; all measurements were also conducted by a single researcher (Y-HL). In some young patients who were uncooperative, deviations were estimated using the Hirschberg or Krimsky test. The surgical objective was to correct for the angle at distance.

The conjunctiva was opened via limbal incision. The distance from the anterior limbus to the midpoint of EOM insertion was measured with a calliper before cutting the muscles (figure 1). In patients who had received surgical treatment in both eyes, only data for the right eye were used to calculate the insertion–limbus distance for comparison with the control subjects and with the subjects in Apt's study.[1] All strabismus procedures were performed according to the surgical guidelines proposed by Wright and Spiegel.[2] Data collection included preoperative deviation, age at surgery, gender, preoperative axial length and follow-up data, including residual deviation.

The control group included 60 consecutive patients who had received an encircling sclera buckle procedure performed by another author of this study (W-CW) during 2007. None of the control patients had a previous diagnosis of strabismus. The procedure for measuring the insertion–limbus distance was as described above. Only data for the treated eye were collected.

Groups were compared using a t test, and correlations between variables were analysed using a Pearson correlation test. A $p<0.05$ was considered statistically significant. A t test was also used to compare insertion locations with those reported in Apt's study.[1] Because not having the raw data of Apt's study, we used case number, mean and SD for t test comparison[3] by using an online t test calculator (please also see http://www.graphpad.com/quickcalcs/ttest1.cfm).

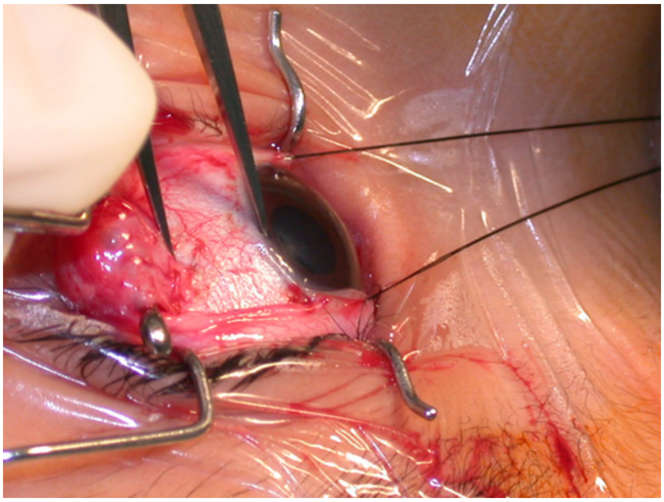

Figure 1 The distance from the anterior limbus to the midpoint of extraocular muscle insertion was measured with a calliper before the muscle was cut. This figure is produced in colour in the online journal—please visit the website to view the colour figure.

RESULTS

The 123 patients in the strabismus group included 54 males and 69 females. Their mean age was 18.5±15.4 years (range, 1.5–62.1 years). Forty (32.5%) patients had esotropia, 73 (59.3%) had exotropia and 10 (8.1%) had other types of strabismus. The mean preoperative deviations in the esotropia and exotropia patients were 36.6±17.4Δ and 35.4±16.7Δ, respectively. Insertion data were available for 109 patients (88.6%; 58 males and 61 females) (table 1). The control group included 40 males and 20 females (mean age, 48.5±15.5 years; age range, 13.3–81.8 years). The muscle insertion locations were not significantly different between the strabismus and control groups. However, the insertion locations for IR, LR and SR were significantly different from those reported in the Apt study (table 2).[1] We arbitrarily separated them into two groups: ≤18 years old and >18 years old. The muscle insertion locations of MR, IR, LR and SR were all more anterior in the younger group (MR: 5.27 vs 5.37; IR: 5.50 vs 6.50; LR 6.54 vs 6.55; SR 7.00 vs 7.25, respectively). However, they all did not reach the statistically significant level (p=0.389, 0.075, 0.951, 0.578, respectively).

In the strabismus group, follow-up data were available for 108 (87.8%) patients. The mean follow-up time was 45.9±67.4 weeks (range, 0.4–299.9 weeks). The mean residual deviations at 1 week, 1 month and 3 months were +1.4±7.7Δ (95% CI, −0.1 to 2.9Δ), −0.4±8.9Δ (95% CI, −2.2 to 1.4Δ) and −0.8±10.7Δ (95% CI, −3.6 to 1.9Δ), respectively, where the minus and plus signs indicate undercorrection and overcorrection, respectively. Residual deviation <10Δ was observed in 86.0% (95% CI, 79.3% to 92.7%), 81.6% (95% CI, 73.8% to 89.4%) and 78.3% (95% CI, 67.6% to 89.1%) of the patients at 1 week, 1 month and 3 months, respectively.

The LR insertion location was significantly associated with axial length in the right eye (r=0.477, p=0.002) but not in the left eye (r=0.274, p=0.087). The IR, LR and SR correlated with other muscle insertion locations, but the MR did not (IR and LR, r=0.354, p=0.005; IR and SR, r=0.424, p=0.001; LR and SR, r=0.270, p=0.032).

In the 42 (38.9%) patients with follow-up >24 weeks, the mean deviation at the most recent follow-up was −3.1±11.7Δ (95% CI −6.8 to 0.5Δ); of these patients, 31 (73.8%) had mean deviations within 10Δ (95% CI 59.9 to 87.7%). Only 26 (24.0%) patients had follow-up data >1 year. In these 26 patients, the mean deviation at the most recent follow-up was −4.0±8.8Δ (95% CI −7.6 to −0.5Δ); 20 patients (80.8%; 95% CI 64.5 to 97.0%) had mean deviations within 10Δ (table 3).

The exotropia patients (n=68) included 31 males and 37 females. Their mean age was 18.7±13.5 years (95% CI 15.5 to 22.0 years). The mean follow-up time was 29.2±42.4 weeks (95% CI 18.9 to 39.4 weeks). Fifty-four (79.4%) patients were within 10Δ at the most recent follow-up. Ten (14.7%) and four (5.9%) patients were undercorrected and overcorrected, respectively. Of the patients who received two-muscle surgery (n=45), those who received MR resection and LR recession tended to have overcorrection (most recent mean deviation=1.6±7.2Δ), while those who received bilateral LR recession tended to have undercorrection (most recent mean deviation=−2.9±6.9Δ; p=0.042).

The esotropia group (n=32) included 11 males and 21 females. Their mean age was 14.7±15.7 years (95% CI 9.1 to 20.4 years). Twenty-six (81.3%) patients were within 10Δ at the most recent follow-up; 5 (15.6%) patients were undercorrected and 1 (3.1%) was overcorrected. The case number was too small for further meaningful comparisons.

DISCUSSION

The results of this study demonstrate that the distances from insertion to the anterior limbus of IR, LR and SR (but not MR) observed in Western populations were significantly longer than those observed in Taiwanese populations. The insertion of the MR seems to be the most reliable and invariant of the rectus muscles in all patients regardless of their ethnic background. Intuitively, the larger the eyeball (ie, the longer its axial length), the more posterior the insertion location of the EOMs would be. Myopia is reportedly an endemic condition in Taiwan[4] and is associated with increased axial length. In the present study, however, the LR insertion location was more anterior than that reported in studies of Western populations. Consistent with Apt,[1] the present study identified no correlation between axial length and EOM insertion location. The orbital volume is reportedly larger in Caucasians than in East Asians.[5] Presumably,

Table 1 Distance from the anterior limbus to the extraocular muscle insertion location: t test comparison of strabismus and control groups

Extraocular muscles	Control n	Control Distance from the limbus (mean±SD; mm)	Strabismus n	Strabismus Distance from the limbus (mean±SD; mm)	p Value
Medial rectus	60	5.2±0.9	73	5.3±0.5	0.304
Inferior rectus	60	6.0±0.8	5	6.1±0.7	0.740
Lateral rectus	60	6.3±0.9	70	6.5±0.7	0.086
Superior rectus	60	6.8±0.7	8	7.1±0.5	0.253

Table 2 Distance from the anterior limbus to the extraocular muscle insertion location: t test comparison with data reported by Apt[1]

Extraocular muscles	Present study n	Present study Distance from the limbus (mean±SD; mm)	Apt[1] n	Apt[1] Distance from the limbus (mean±SD; mm)	p Value
Medial rectus	133	5.3±0.7	100	5.3±0.7	1.000
Inferior rectus	65	6.0±0.8	100	6.8±0.8	<0.001
Lateral rectus	130	6.4±0.8	100	6.9±0.7	<0.001
Superior rectus	68	6.8±0.7	100	7.9±0.6	<0.001

For t test calculation, see http://www.graphpad.com/quickcalcs/ttest1.cfm (13 February 2011).

EOM insertion locations also vary by race. Notably, the present study showed that subjects with and without strabismus have similar insertion locations. Additionally, the muscle insertion locations of the MR, IR, LR and SR were all more anterior in the younger group. However, they all did not reach the statistically significant level. Probably more cases in future prospective study could reveal the differences.

Because the EOM insertion locations observed in the Taiwanese population differed from those observed in Western populations, the important question is whether surgical formulas developed for Western populations are applicable to the populations in Taiwan and elsewhere in Asia. Comparing results reported for different countries has challenges. For exotropic patients, a multicentre study of horizontal strabismus outcomes in the UK reported that 100% of exotropia patients had a mean deviation within 10Δ 6 months postsurgery.[6] In the study by Kushner, 28 of 36 (77.8%) intermittent exotropia patients had satisfactory outcomes (defined as mean deviations within 10Δ for exophoria and within 5Δ for esophoria) 1 year postsurgery.[7] Another study by Kushner reported satisfactory outcomes in 86.0% of intermittent exotropia patients.[8] Notably, the definitions of satisfactory outcome in both studies were stricter than that in the current study. The results reported for Western populations (approximately 80–100% satisfactory outcomes) were generally more favourable than those observed in the current study (65–80% satisfactory outcomes).

A Japanese study of patients who had received surgery for intermittent exotropia reported successful outcomes in 60.2% of patients 1 month postsurgery.[9] Similarly, a Singaporean study reported successful outcomes (≤10Δ) in 67 of 118 (56.8%) patients with intermittent exotropia 1 year postsurgery.[10] A Korean study reported successful outcomes in 43.9% of subjects surgically treated for basic intermittent exotropia 21 months postsurgery.[11] Interestingly, based on the above studies, patient outcomes of exotropic surgery (45–60% successful) have generally been lower in Asian populations than in Western populations.

Table 3 Strabismus surgery results

Cases	Within 10Δ, n (%)	Undercorrection, n (%)	Overcorrection, n (%)
All (n=108)	87 (80.6)	16 (14.8)	5 (4.6)
Esotropia	26 (81.3)	5 (15.6)	1 (3.1)
Exotropia	54 (79.4)	10 (14.7)	4 (5.9)
Other	7 (87.5)	1 (12.5)	0
Follow-up >24 weeks (n=42)			
Esotropia	13 (76.5)	3 (17.6)	1 (5.9)
Exotropia	13 (65.0)	6 (30.0)	1 (5.0)
Other	5 (100.0)	0	0
Subtotal	31 (73.8)	9 (21.4)	2 (4.8)
Follow-up >1 year (n=26)			
Esotropia	10 (76.9)	3 (23.1)	0
Exotropia	9 (81.8)	1 (9.1)	1 (9.1)
Other	2 (100.0)	0	0
Subtotal	21 (80.8)	4 (15.4)	1 (3.8)

In the multicentre study from the UK, 91% of the esotropic patients had achieved a mean deviation within 10Δ 6 months after horizontal strabismus surgery.[6] Another study by Ing reported that 45% of patients with infantile esotropia required additional surgery within 6 months of horizontal strabismus surgery. Of these, 33% required vertical muscle surgery.[12] Accordingly, about 80–90% of their esotropic patients were satisfied with the correction for horizontal deviation. In Helveston *et al*, 7 of 10 congenital esotropic patients achieved horizontal success after one surgery.[13] A study in Turkey reported a 66.6% success rate in surgery for infantile esotropia.[14] A 4-year follow-up study of nine patients who had received early surgery for infantile esotropia in Japan found that esotropia was <10Δ in eight of the nine patients.[15] The variation in these outcomes may be due to the confounding effects of amblyopia, dissociated vertical deviation and inferior oblique overaction. Overall, the esotropic surgery outcomes observed in the current study were no worse than those reported in other countries.

According to the surgical guidelines proposed by Wright and Spiegel, a 1 mm difference in recession of both LRs can produce a deviation error of 5–10Δ.[2] Compared with Western populations, the LR insertion location was more anterior (average, 0.5 mm) in the Taiwanese population. Undercorrection was observed in a significant portion (10–30%) of the exotropia patients, likely due to the more anterior LR insertion location. This may explain why patients who received bilateral LR recession in this study had a significantly higher incidence of undercorrection compared with patients who received MR resection and LR recession. It has been recommended by some investigators that basic type of intermittent exotropia should be treated with unilateral recess/resect surgery[16]; however, our study included various types of exotropia. For surgical treatment of esotropia, some studies suggest that recession amount of the MR muscle should be measured from the corneaoscleral limbus.[17 18] However, later studies showed that differences in MR recession amount from the original insertion may explain the different outcomes reported in the literature.[19] From our data, the MR insertion location was relatively invariant of the rectus muscles in all patients regardless of their ethnic background. Unfortunately, the case number of esotropia in current study was too small to have meaningful comparisons (bilateral recession vs unilateral recession-resection). Additionally, the extent to which observations reported in cases of congenital esotropia can be extrapolated to cases of exotropia needs further study. If the variations in our surgical results were due to variations in muscle insertion or just merely due to different ethnicities, it requires further study with more detailed strabismus types to answer this question, too.

Because this retrospective study only classified the patients into exotropic, esotropic and other types of strabismus groups, the results should be interpreted with caution. Since the data in this retrospective study were only compared with those reported by Apt, prospective studies are needed for further confirmation. Additionally, the mean age of the control group was not matched with that of the strabismus group. However, the mean age in both groups was >18 years and the growth of the orbital volume approaches adult level by 15 years of age[20]; thus, we suggest that the age had a minor effect in our insertion analysis study. With globalisation, the 'pure' ethnic difference will be more and more difficult to be detected in the future.

In summary, this study revealed ethnic differences in EOM insertion locations that may affect surgical outcomes. However, whether ethnic differences in EOM insertion locations increase the prevalence of exotropia in Asian populations needs future study. Further studies with more detailed classifications of strabismus types and more detailed comparisons of different surgical procedures and their relation to EOM insertion locations among different races are recommended.

Acknowledgements We are indebted to Dr CS Hoyt for his helpful criticism of this manuscript.

Funding This study was supported by Kaohsiung Medical University Hospital grant KMUH98-8G12.

Competing interests None.

Ethics approval This study was approved by the Institutional Review Board, Kaohsiung Medical University Hospital, Kaohsiung, Taiwan.

Contributors Y-HL: conception and design; analysis and interpretation of data; drafting the article; revising it critically for important intellectual content. W-CW: conception and design; analysis and interpretation of data. H-ZW: conception and design; analysis and interpretation of data. H-TH: drafting the article; final approval of the version to be published.

Provenance and peer review Not commissioned; externally peer reviewed.

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Br J Ophthalmol published online January 12, 2012
doi: 10.1136/bjophthalmol-2011-300632

Notes