Ultrasound of the Horizontal Rectus Muscle Insertion Sites: Implications in Preoperative Assessment of Strabismus

Ciro Tamburrelli, Tommaso Salgarello, Agostino Salvatore Vaiano, Luigi Scullica, Marino Palombi, and Bruno Bagolini

PURPOSE. To determine the reproducibility and accuracy of ultrasonographic (US) measurements of distances between the corneoscleral limbus and the insertion site of the medial (MR) or lateral rectus (LR) muscle compared with intraoperative measurements in patients with strabismus.

METHODS. One eye in each of 17 patients with postoperative secondary strabismus caused by over- or undercorrected eso- and exotropia and one eye of each of 19 patients with previ- ously untreated strabismus underwent five repeated measurements by high-resolution ultrasonography of the distance from the corneoscleral limbus to the muscle insertion and three actual intraoperative measurements. Reproducibility, ex- pressed as the coefficient of variation, accuracy (relative error) of US measurements, and the agreement with intraoperative measurements were assessed.

RESULTS. The coefficients of variation for US data were 2.02% and 3.18% for the MR and 7.33% and 11.77% for the LR, in the surgical and untreated groups, respectively. The relative error was 6.15% ± 8.14% (mean ± SD) and 3.66% ± 12.83% for the MR muscle, and 12.21% ± 10.66% and −7.69% ± 7.83% for the LR muscle, in the surgical and untreated groups, respectively. The 95% limits of agreement (mean ± 2 SD) between the US and intraoperative measurements were 0.65 ± 1.82 and 0.15 ± 1.42 mm for the MR muscle, and 1.12 ± 2.01 and −0.49 ± 0.98 mm for the LR muscle, in the surgical and untreated groups, respectively.

CONCLUSIONS. The results indicate good reliability and accuracy of US readings and suggest a potential usefulness in preoperative assessment of patients with strabismus with surgical failure and missing preoperative clinical data. (Invest Ophtalmol Vis Sci. 2003;44:618–622) DOI:10.1167/iovs.02-0112

The knowledge of the exact distances between the corneoscleral limbus and the insertion sites of rectus muscles is important in the calculation of the amount of recession to be performed in strabismus surgery. As to the medial rectus (MR) muscle, although it has been classically reported to insert 5.5 mm from the corneoscleral limbus,1 recent studies of healthy humans2 and of patients with infantile esotropia3–5 have shown considerable variation in this distance. In recognition of this variability, surgical formulas for the treatment of esotropia have evolved that are based on grading the recession operation from the corneoscleral limbus.6,7 The acquisition of these data becomes even more relevant in strabismus reoperations, be- cause the insertion site has been surgically modified.

Secondary exotropia (exotropia after surgery for esotropia) is a common problem for ophthalmologists. Between 4% and 20% of all patients who undergo surgery for esotropia experi- ence development of secondary exotropia.8,9 In this condition as well as in residual esotropia, the data on muscles treated surgically (i.e., the procedure performed and its amount) are usually collected in the patients’ clinical charts; however, de- tailed information is sometimes missing. For this purpose, we propose the use of ultrasound (US) to evaluate the tendon insertion site of recessed muscles by measurement of the distance from insertion site to the corneoscleral limbus. No useful information can be obtained in previously resected mus- cles, because no quantitative changes of the muscle insertion site have occurred.

The purpose of this study was to determine the accuracy and reproducibility of US measurement of the distance between corneoscleral limbus and the horizontal extraocular muscle insertion in comparison to intraoperative measurements, to evaluate its clinical use in preoperative assessment of patients with either secondary exotropia or residual esotropia.

MATERIALS AND METHODS

Subjects

Seventeen patients with strabismus (nine boys, eight girls; mean age ± SD: 12.9 ± 5 years) with surgical failure (undercorrected esotropia or exotropia and overcorrected esotropia), scheduled to undergo further surgery, were included in the study. Each patient had had a single operation, either in our eye clinic or elsewhere.

A second group of 19 patients (10 boys, 9 girls; mean age ± SD: 13.4 ± 8.8 years) with infantile, acquired nonaccommodative or partly accommodative esotropia, and congenital or acquired exotropia were enrolled in the study as a separate group. No patient had had strabismus surgery, mechanical restrictions, or nystagmus.

Both eyes of each patient underwent US measurements of the corneoscleral limbus to muscle insertion site distance on horizontal extraocular muscles with the calipers of the scanning unit (Biovision B-Scan "S" Vplus unit; Quantel Medical, Clermont-Ferrand, France). To obtain good cooperation for reliable US measurements the lower age limit for the inclusion in both groups was established at 5 years. Demographic and clinical data from both groups are reported on Tables 1 and 2.

The US examiner was masked to all clinical data, and surgery was performed within 2 weeks of US examination. All US measurements were performed by one operator (CT), and all intraoperative measurements were performed by one surgeon (BB). Both examiners were masked to the other’s measurements.

Informed consent was obtained from all participants after the procedures used in the study were fully explained. The research complied with the tenets of the Declaration of Helsinki.
US, ultrasonographic reading of the insertion muscle site to corneoscleral limbus distance; Surgery, actual intraoperative measurement of the insertion muscle site to corneoscleral limbus distance; RE, right eye; LE, left eye; XT, exotropia; ET, esotropia.

* Refractive error expressed as spherical equivalent.
† Means of five repeated measurements ± SD.
‡ Means of three repeated measurements ± SD.

US Measurements

We used a new-generation B scanner that has a focal length of 24 mm, a sector scan pattern probe, and a frequency emission of 10 MHz, to measure before surgery the distance between muscle tendon insertion site and the corneoscleral limbus. In all cases, it was computed by setting the US unit at the standard velocity for soft tissue of 1550 m/sec.10 Such a velocity is commonly used for US assessment of orbital tissues.11-12 Indeed, in measuring acoustic properties of normal human orbital tissues, Buschmann et al.13 reported sound velocities ranging from 1462 (in fat) to 1631 m/sec (external eye muscles).

The muscle insertion site area was examined with the probe placed in contact with bulbar conjunctiva or more frequently with the skin of closed eyelids, especially in children, because it is more easily accepted. The minimal sound attenuation determined by the eyelids does not affect the quality of the images obtained, because an optimal display of orbital details still requires a lowering of the maximal US gain. The probe was placed on the temporal or nasal side for MR or

TABLE 2. Demographic and Clinical Data from the Group without Prior Surgery

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age (y)</th>
<th>Sex</th>
<th>Eye</th>
<th>Refractive Error * (D)</th>
<th>Deviation Angle (Prism Diopters)</th>
<th>US (mm)</th>
<th>Surgery (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial Rectus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>16</td>
<td>F</td>
<td>RE</td>
<td>+1.25</td>
<td>ET = 30</td>
<td>6.10 ± 0.29†</td>
<td>6.00 ± 0.13‡</td>
</tr>
<tr>
<td>19</td>
<td>17</td>
<td>M</td>
<td>LE</td>
<td>+3.75</td>
<td>XT = 30</td>
<td>6.50 ± 0.14</td>
<td>7.55 ± 0.13</td>
</tr>
<tr>
<td>20</td>
<td>11</td>
<td>M</td>
<td>LE</td>
<td>+1.00</td>
<td>ET = 30</td>
<td>5.21 ± 0.16</td>
<td>5.16 ± 0.15</td>
</tr>
<tr>
<td>21</td>
<td>48</td>
<td>F</td>
<td>LE</td>
<td>-1.50</td>
<td>ET = 45</td>
<td>5.31 ± 0.12</td>
<td>5.45 ± 0.02</td>
</tr>
<tr>
<td>22</td>
<td>11</td>
<td>F</td>
<td>RE</td>
<td>+1.75</td>
<td>ET = 30</td>
<td>5.88 ± 0.49</td>
<td>6.66 ± 0.11</td>
</tr>
<tr>
<td>23</td>
<td>10</td>
<td>F</td>
<td>LE</td>
<td>+2.00</td>
<td>ET = 30</td>
<td>5.72 ± 0.68</td>
<td>6.75 ± 0.05</td>
</tr>
<tr>
<td>24</td>
<td>7</td>
<td>F</td>
<td>RE</td>
<td>-1.25</td>
<td>ET = 35</td>
<td>5.55 ± 0.10</td>
<td>5.10 ± 0.05</td>
</tr>
<tr>
<td>25</td>
<td>9</td>
<td>M</td>
<td>LE</td>
<td>+4.25</td>
<td>ET = 30</td>
<td>5.26 ± 0.24</td>
<td>5.10 ± 0.00</td>
</tr>
<tr>
<td>26</td>
<td>8</td>
<td>M</td>
<td>RE</td>
<td>-0.25</td>
<td>ET = 30</td>
<td>6.88 ± 0.19</td>
<td>5.15 ± 0.05</td>
</tr>
<tr>
<td>Mean</td>
<td>15.6</td>
<td>M</td>
<td>RE</td>
<td>+2.75</td>
<td>ET = 35</td>
<td>5.61 ± 0.62</td>
<td>5.46 ± 0.76</td>
</tr>
</tbody>
</table>

| Lateral Rectus |
| 29 | 13 | F | LE | +1.75 | ET = 40 | 5.34 ± 0.19 | 5.20 ± 0.00 |
| 30 | 12 | M | RE | +1.50 | ET = 20 | 5.00 ± 1.08 | 5.95 ± 0.05 |
| 31 | 8 | F | RE | +2.25 | ET = 20 | 5.20 ± 0.29 | 6.06 ± 0.05 |
| 32 | 13 | M | RE | -1.75 | XT = 35 | 5.89 ± 0.49 | 6.66 ± 0.11 |
| 33 | 11 | M | LE | +3.00 | XT = 35 | 5.72 ± 0.68 | 6.75 ± 0.05 |
| 34 | 11 | F | RE | -1.25 | ET = 15 | 6.71 ± 0.77 | 6.53 ± 0.05 |
| 35 | 13 | F | LE | +0.75 | ET = 25 | 6.46 ± 1.27 | 6.1 ± 0.10 |
| 36 | 12 | M | RE | +1.00 | ET = 20 | 5.73 ± 0.69 | 6.21 ± 0.05 |
| Mean | 5.76 ± 0.60 | 6.25 ± 0.51 |

Data are expressed as described in Table 1.
lateral rectus (LR) muscle examination, respectively. To obtain a longitudinal scan of the rectus muscles allowing for a simultaneous visualization from the limbus up to the muscle belly through its inserting tendon, the reference of the B-scan probe (corresponding to the top of the screen) was directed toward the cornea, and the scanning plane was oriented parallel to the long axis of the muscle. We conventionally use this technique to display the muscle with inserting tendon pointing toward the top of the screen and the belly to the bottom (Fig. 1). In primary-gaze position, the limbus and muscle insertion site remain too anterior in relation to the US scanning sector to be displayed; therefore, patients were asked to look in the direction opposite to the probe. The maximum contraction induced on the examined muscle allows the tendinous insertion to fall in the scanning sector of the probe and the muscular arc of contact (region of tangency between extraocular muscles and globe) to disappear, so that the posterior face of the insertion becomes clearly identifiable for US measurements. When the proper scanning plane was displayed, the image was frozen, and measurements were taken.

The corneoscleral limbus is a transitional zone between the transparent cornea and the opaque sclera. Because it is not ultrasonographically visible with a 10-MHz probe, its location was assessed in relation to the easily identifiable iris root–anterior chamber angle complex. Specifically, the caliper was placed 0.9 mm anterior to the projection on the corneoscleral surface of the shortest imaginary line from the iris root. Anatomic studies have reported the surgical limbus to be 1.0 to 1.1 mm anterior to the deepest portion of the anterior chamber angle, and this distance is increased in myopic eyes and reduced in hyperopic and immature eyes. We choose 0.9 mm, because the hyperopic eyes were largely represented in our study population.

Five consecutive readings were taken on two separate occasions within 3 days, and the mean and SD were calculated. Test-retest variability of the US measurements, expressed by the average of the SDs of the biometric values in the five images, was 0.55 ± 0.31 mm in surgically treated eyes and 0.35 ± 0.39 mm in untreated eyes. More precisely, its value corresponded to 0.25 ± 0.09 mm for the MR muscle and 0.81 ± 0.15 mm for the LR muscle of the surgical eyes and 0.18 ± 0.08 mm for the MR muscle and 0.68 ± 0.37 mm for the LR muscle of the untreated eyes.

Direct Measurements

During surgery, the distance of the insertion site of the MR or LR muscle from the corneoscleral limbus was assessed. The muscle insertion site was classically measured where the most anterior muscle tendon fibers visibly attach to the sclera, halfway between the superior and inferior poles of the insertion. This site corresponds to the location where the MR or LR muscle tendon is attached to the sclera before disinsertion and where the rectus muscle stump remains after disinsertion of the muscle. The corneoscleral limbus was measured at the anterior junction between the transparent cornea and the gray of the corneoscleral limbus. The distance was measured with a Castroviejo caliper, and subsequently the tips of the caliper were placed on each jaw of a vernier caliper for higher precision. All measurements were repeated three times, and the mean ± SD was calculated. Test-retest variability of the intraoperative data, expressed by the average of the standard deviations of the three measurements, was 0.21 ± 0.12 mm in surgical eyes and 0.07 ± 0.05 mm in untreated eyes. More precisely, its value corresponded to 0.19 ± 0.17 mm for the MR muscle and 0.23 ± 0.04 mm for the LR muscle of the surgical eyes, and to 0.08 ± 0.06 mm for the MR muscle and 0.06 ± 0.03 mm for the LR muscle of the untreated eyes.

Statistical Methods

US and intraoperative measurements from one eye per patient, randomly selected if the last surgery was bilateral, were included in the statistical analysis. Two separate analyses were performed on US and direct measurements, according to the patient’s group and the rectus muscle.

An independent Student’s t test was used on the sets of US measurements from the two patient groups, as a whole and as two separate subgroups according to the extraocular muscle, to assess the US capability to recognize that the corneoscleral limbus-to-insertion site distance data were collected from different groups.

The coefficient of variation was calculated as the square root of the mean variance of the US measurements obtained from each subject and then divided by the mean measured US corneoscleral limbus-to-insertion site distance and reported as a percentage. We choose the coefficient of variation as a measure of reproducibility, because it is straightforward and enabled us to compare our results to those of other investigators. The US readings of each patient were compared to the actual intraoperative measurements to obtain the relative error of the single observations.

The discrepancy between corresponding readings obtained by the two measurements was individually calculated, and the mean ± SD was used to compute the 95% limits of agreement between the US and intraoperative readings (mean ± 2 SD) in both groups for MR and LR muscles.

RESULTS

The sets of readings (mean of repeated measurements ± SD) obtained from the study group with surgical failure (17 eyes) and no previous surgery (19 eyes) are reported in Tables 1 and 2, respectively. In the first group the corneoscleral limbus-to-insertion site measurements ranged from 9.20 to 22.00 mm (12.36 ± 4.22, mean ± SD) and from 9.35 to 22.20 mm (11.71 ± 4.34) for the MR muscle and from 10.85 to 11.20 mm (11.05 ± 0.14) and from 9.16 to 11.25 mm (9.92 ± 0.96) for the LR muscle, with US and intraoperative caliper, respectively. The large value of the measurement in case 2 was related to a
surgically slipped MR. In the second group, the measurements ranged from 4.93 to 6.88 mm (5.61 ± 0.62) and from 4.85 to 7.55 mm (5.46 ± 0.76) for the MR muscle and from 5.00 to 6.71 mm (5.76 ± 0.60) and from 5.20 to 6.75 mm (6.25 ± 0.51) for the LR muscle, with US and intraoperative caliper, respectively.

The US readings differed significantly between the surgical and untreated groups (P < 0.05) by independent Student’s t-test, when considering either the whole group or the surgically treated muscle.

Table 3 shows coefficient of variation, relative error, and 95% limits of agreement from patients’ eyes according to the surgically treated muscle or intervention condition. The coefficients of variation for US data were 2.02% and 3.18% for the MR muscle, and 7.33% and 11.77% for the LR muscle, in the surgical and untreated groups, respectively. The relative error was 6.15% ± 8.14% (mean ± SD) and 3.66% ± 12.83% for the MR muscle, and 12.21% ± 10.66% and −7.69% ± 7.83% for the LR muscle, in the surgical and untreated groups, respectively. The 95% limits of agreement (mean ± 2 SD) between the US and intraoperative measurements were 0.65 ± 1.82 and 0.15 ± 1.42 mm for the MR muscle, and 1.12 ± 2.01 and −0.49 ± 0.98 mm for the LR muscle, in the surgical and untreated groups, respectively.

**DISCUSSION**

Surgical under- and overcorrection of horizontal tropia is a problem that frequently confronts the strabismus surgeon. Inadequate preoperative evaluation, high hyperopia, amblyopia, and insufficient or excessive correction have been mentioned as responsible factors.17–21 Therefore, a careful preoperative evaluation is mandatory for the management of consecutive strabismus. However, information on the preoperative condition and the surgical procedure performed may be inaccessible, because the same surgeon (or sometimes a different one) may be called on to treat secondary strabismus even many years later. Preoperative images, parents’ reports, and the slit lamp examination of conjunctival scars may be the only available means to obtain information on the clinical history. Because of postoperative alterations in anatomy,22 other data are collected before surgery with the “duction test,” and during surgery, checking whether, for example, a Faden operation or a vertical displacement was performed and measuring the corneoscleral limbus-to-insertion muscle site distance.23

Orbital imaging techniques can be helpful in the preoperative evaluation of patients without available information regarding prior surgery, provided that the corneoscleral limbus and insertion muscle can be clearly displayed. For this purpose, we propose the use of US to detect surgical muscle recession by measurement of corneoscleral limbus-to-insertion site distance.

Other imaging techniques include computed tomographic (CT) scans and high-resolution magnetic resonance imaging (MRI), which can demonstrate the origin and course of the extraocular muscles with sufficient detail. Cine MRI, which is performed in different gaze positions to produce a video recording of ocular movements,24 has also been used to analyze restrictive motility disorders.25 MRI is generally superior to CT scans in delineating soft tissues.26 Indeed, various parts of the connective tissue of the extraocular muscles can be well evaluated by MRI because of the sharp contrast between hyperintense orbital fat and hypointense connective structures. However, because of the varying arc of contact and the isointensity of tendon and scleral tissue, an exact determination of the extraocular muscle insertion is not currently possible.27

The high resolution of modern B scanners seems to allow a more effective anatomic visualization and measurement of extraocular muscles and the detection of subclinical changes in muscle size.28–29 The real-time display, the smaller length of the US examination, and lower cost are additional advantages of this technique.

We studied the reliability of US readings of the distance from the corneoscleral limbus to the insertion site of the MR and LR muscle in two groups of patients, with either surgical strabismus failure or with untreated strabismus, evaluating the degree of agreement with intraoperative measurements and their reproducibility.

Ultrasound test-retest variability was greater in comparison to intraoperative direct measurement. This difference was most significant for the MR muscle (0.81 and 0.68 mm vs. 0.25 and 0.20 mm for the LR muscle) and for the MR muscle (0.25 and 0.20 mm vs. 0.08 mm for the MR muscle, in the operated and untreated eyes, respectively). Possible explanations of the LR finding, in our opinion, are related to more difficulty in identifying the US landmarks for the LR than for the MR muscle. Indeed, a good visualization of these landmarks (i.e., the inserting tendon and the anterior chamber angle) needs both a maximally posterior probe angle, limited by the nose in the LR muscle examination, and extreme duction, physiologically less effective for the LR than for the MR muscle.

When considering the coefficient of variation, the US measurements were reliable, especially in the group of patients who underwent surgical recession and for the MR muscle. As to the surgical group, the good reproducibility may be due to the greater mean distance from limbus to muscle insertion site of the recessed muscles (12.36 and 11.05 mm in the surgical eyes vs. 5.61 and 5.76 mm in the untreated eyes, for the MR and LR muscles respectively), whereas, as to the MR muscle, it may depend on the lower US test-retest variability for this muscle than for the LR one.

The mean relative error for US measurements ranged from −7.69% to 12.21%, showing higher errors in the surgical group than in the untreated one, with larger US than intraoperative measurements in all groups but in the LR muscle of the untreated eyes (see Table 3). This finding is better defined by the 95% limits of agreement (range within which the discrepancies will lie in 95% of cases: −0.49 to 1.12 mm) between US and intraoperative measurements. A major reason for the larger US measurements may be the different point used as reference for the measurements at the muscle insertion site. US readings were performed from the posterior face of the insertion tendon, whereas intraoperative measurements were from its anterior face. Postsurgical alterations in anatomy (i.e., unpredictable adhesions at the posterior face of the recessed tendon) may further influence the disagreement. From another
viewpoint, the difficult US display of the muscle insertion area during LR measurements may account for additional variability.

The clinical use of US for detection and assessment of surgical recession of horizontal rectus muscles depends therefore on the maximum amount of discrepancy found between US and intraoperative measurements. Specifically, adding the mean ± 2 SD of such a discrepancy to the maximum insertion site-to-limbus distance indicated in the literature for the examined muscle in a population of similar age and refractive status, we obtain a value beyond which we can assume a muscle recession was performed. For instance, if we consider the MR rectus muscle of emmetropic eyes, adding the specific discrepancy value (2.47 mm = 0.65 + 1.82, mean ± 2 SD) to the maximum value classically reported for the insertion site-to-limbus distance by Fuchs to cadaveric eyes (6.7 mm), we obtain 9.17 mm. Each US insertion site-to-limbus distance exceeding such a value may reasonably indicate that a surgical recession was performed. Nevertheless, a quantitative evaluation of the amount of performed recession seemed not to be particularly accurate.

In conclusion, we found echographic measurements to be reliable with good indices of reproducibility; however, the 95% limits of agreement between US and actual intraoperative readings may be considered too inadequate to use US for research purposes. US evaluation is harmless, inexpensive, well tolerated, and repeatable, but it requires a skilled US examiner. Although the accuracy is not particularly high, US provides better visualization of the insertion muscle site–limbus region compared with other imaging techniques. Specifically, its use in surgically treated horizontal rectus muscles could allow for the detection and assessment of surgical recession, as well as the recognition of the real insertion, sometimes postsurgically modified by unpredictable adhesions. Thus, besides the well-known role of echography in the diagnosis of extraocular muscle disorders, the present study suggests a further potential use of the technique in patients with strabismus with surgical failure and missing preoperative clinical data.

References