Adjustable Sutures in Children Using a Modified Technique

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Purpose: Adjustable-suture techniques are commonly used to decrease the reoperation rate in adults undergoing strabismus surgery, but they are infrequently used in children because of the difficulty of performing adjustments on a conscious child. The purpose of this study is to evaluate a new technique for using adjustable sutures in children, which makes the second stage of the procedure unnecessary if no adjustment is needed. ***Methods:*** This was a retrospective study of children who underwent surgery for exotropia or esotropia. The technique used was a variation of the standard fornix-based adjustable suture with a separate slipknot. The pole sutures were buried within the sclera and tied; then the incision of the conjunctiva was closed to cover the adjustable sutures. The patients were then measured 4 to 6 hours after the initial surgery. The decision of whether to adjust was based on predetermined criteria. Those children not adjusted were discharged with no further manipulation needed because the conjunctiva was already closed. For those children who were adjusted, the adjustment was made with the patient under intravenous propofol sedation or laryngeal mask anesthesia. ***Results:*** A total of 61 consecutive children ages 12 months to 14 years underwent surgery using this technique. Patients were followed-up after surgery for a minimum of 6 weeks (median 19.4). Fifty-four of the 61 patients (88%) were within 10 prism diopters (**PD**) of orthophoria on their final postoperative visit. Of the 22 patients who underwent an adjustment, 20 (91%) were within 10 PD of orthophoria at their final postoperative visit. The median follow-up was 19.4 weeks (range 6 to 45.9). ***Conclusions:*** This new adjustable-suture technique was associated with excellent short-term eye alignment. It is particularly suited for pediatric surgery because it eliminates the necessity of further manipulation of children who do not require adjustment. (J AAPOS 2004;8:243-248)

Adjustable sutures are frequently used in adults to improve immediate postoperative alignment.[1] However, adjustable sutures are not commonly used in children because of the difficulty in obtaining their cooperation during postsurgical manipulation.

In the standard method of adjustable strabismus surgery, the pole sutures are left exposed after the initial operation. This requires tying the sutures and sometimes closing the conjunctiva even if adjustment of the muscle is not necessary. This is difficult to do in children unless they are heavily sedated or under general anesthesia. Because adjustment is not considered necessary in the majority of cases, it is hard to justify the use of a second anesthetic in every child to use adjustable sutures.

We have developed a modification of the adjustable-suture technique in which no manipulation is performed if the muscle is not adjusted. This is accomplished by burying the pole sutures in the sclera in the area of the fornix incision and then completely closing the conjunctival incision over the adjustable sutures. Because no sutures are left exposed after the surgery, no further manipulation is needed if an adjustment is unnecessary. Only children who were significantly misaligned after surgery and who were judged likely to benefit from adjustment according to predetermined criteria underwent additional anesthesia. We present the methods and results of children undergoing strabismus surgery using this modified technique.

METHODS

Internal Review Board approval was obtained from Robert Wood Johnson University Hospital for a retrospective study of patients < 16 years old undergoing strabismus surgery for horizontal strabismus using a modified adjustable-suture technique. The study included all 61 patients < 16 years who underwent surgery for horizontal strabismus by the primary investigator, who performed all the surgeries, from August 29, 2001, to August 31, 2002. All 61 patients had 1 horizontal muscle placed on an adjustable suture. We decided not to exclude any patient < 16 years old who underwent strabismus surgery of the horizontal muscles during this time period to avoid any selection bias. Therefore, the study included patients with preexisting conditions such as amblyopia, previous strabismus

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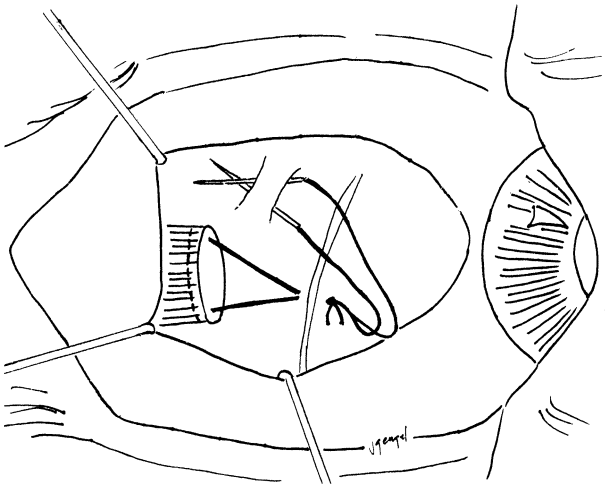

FIG 1. A separate scleral pass is made in the area of the fornix incision using S-29 spatulated needles, which are then securely tied down and trimmed to prevent slippage.

surgery, or Duane's syndrome. Only those patients who underwent surgery for a primarily vertical deviation or who were ≥ 16 years old were excluded. All patients were followed-up for at least 6 weeks after surgery. Before surgery, informed consent—including informed consent for a possible second surgical procedure involving the adjustment of the muscle with the patient under intravenous or general anesthesia—was obtained from the parents or the patient's legal guardian.

Surgical Technique

Standard fornix technique was used on all patients. One horizontal muscle was placed on an adjustable suture as described by Jampolsky.[2] A separate slipknot was placed around the sutures connected to the muscle (the pole sutures). The muscle was allowed to hang back from the partial-thickness scleral tunnels in the original insertion line; the amount hung back on was based on preoperative measurements of the patient's strabismus. A separate partial-thickness scleral pass was then made in the area of the fornix incision such that there was an additional 6 or 7 mm of suture left beyond the adjustable knot (Figure 1). The pole sutures were then tied, and any excess suture was trimmed to approximately 2 mm from the knot. Tying the knot secured the muscle so that it could not slip. The conjunctiva was then closed with 7-0 gut chromic sutures, thereby covering all the sutures and the muscle.

Postoperative Assessment and Adjustment

Patients were evaluated 3 to 5 hours after the initial surgery in a private room. In some children tetracaine was placed in the eyes to facilitate the postoperative measurement. Measurements of each patient's motility were taken using an alternate-cover test with prisms while the child fixated on a distance target (either a videotape or a finger puppet) and a near target (a finger puppet). If the child was not initially cooperative, he or she was allowed to rest and was then re-examined within 2 hours. Whether to adjust the muscle was based on predetermined criteria (Table 1). These criteria were developed based on recommendations by Wright[3] and our own clinical experience using distance measurements and the type of surgery. Although the decision to adjust or not was based on predetermined criteria, the number of millimeters the muscle should be repositioned was a clinical decision based on the patients' response to the surgery already performed, the age of the patient, the immediate distance and near postoperative measurements, and our previous experience with similar patients. The children for whom adjustment was not indicated were discharged. The 22 children requiring adjustments were adjusted in the operating room under intravenous propofol sedation or with a brief general anesthesia administered either with mask only or with a laryngeal mask airway. The children had an intravenous line in place from the primary surgery and were allowed clear liquids up to 2 hours before the adjustment. All children were adjusted 4 to 7 hours after the original surgery. Surgical time for the adjustments was within 15 minutes for all patients.

TABLE 1. Criteria for Adjustment

Diagnosis	Operation	Criteria for Adjustment* (PD)
Esotropia	MR recessions/Both eyes	ET ≥ 12 or XT ≥ 8
	MR recession/One eye	ET ≥ 8 or XT ≥ 4
	MR recession/LR resection	ET ≥ 8 or XT ≥ 4
Exotropia	LR recessions/Both eyes	ET ≥ 15 or XT ≥ 0
	LR recession/One eye	ET ≥ 8 or XT ≥ 4
	LR recession/MR resection	ET ≥ 8 or XT ≥ 4

ET: esotropia; *LR:* lateral rectus; *MR:* medial rectus; *PD:* prism diopters; *XT:* exotropia.
*Distance measurements were used.

Surgical Technique for Adjustment

Once the child was sedated, tetracaine was placed in the eye. An eyelid speculum was placed. The area of the fornix incision was opened, and the pole sutures were exposed. The muscle was adjusted using standard techniques for adjustable sutures. The pole sutures were then tied with tying forceps, the sutures trimmed to within 2 mm of the knot, and the fornix incision closed with 1 or 2 7-0 gut chromic sutures.

Postoperative Measurements

The children were discharged after recovering from the second anesthesia, and no further measurements were obtained that day. Except for 1 child for whom the first measurement after the day of surgery was at postoperative day 6, standard measurements were taken for all children by the third day after surgery. The last follow-up measurement taken was considered the final postoperative measurement.

TABLE 2. Summary of Patients with Exotropia

Type of Operation	No. of Patients	No. (%) Patients Adjusted	No. (%) Success (Within 10 PD of Orthophoria)	No. (%) Previous Surgery or Pre-Existing Condition*
Recess 1 LR	16	5 (31)	16 (100)	4 (25)
Bilateral LR recess	11	5 (45)	9 (81)	7 (64)
Recess LR/resect MR	5	3 (60)	4 (80)	2 (40)
Total	32	13 (41)	29 (91)	13 (41)

LR: lateral rectus; *MR:* medial rectus; *PD:* prism diopters; *recess:* recession; *resect:* resection.
*Number (percentage) of patients who had previous surgery (n = 7) or ≥ 1 of the following: developmental delay (n = 4), partial nerve palsy (n = 1), Duane's retraction syndrome (n = 0), or visual acuity ≤ 20/200 PD in 1 eye (n = 1).

TABLE 3. Summary of Patients with Esotropia

Type of Operation	No. of Patients	No. (%) of Patients Adjusted	No. (%) of Success (Within 10 PD of Orthophoria)	No. (%) of Previous Surgery or Pre-Existing Condition*
Bilateral MR recess	20	4 (20)	17 (85)	2 (10)
Recess 1 MR†	7	4 (57)	7 (100)	4 (57)
Recess MR/resect LR	2	1 (50)	1 (50)	1 (50)
Total	29	9 (31)	25 (86)	7 (24)

LR: lateral rectus; *MR:* medial rectus; PD, prism diopters; *recess:* recession; *resect:* resection.
*Number (percentage) of patients who had previous surgery (n = 3) or ≥ 1 of the following: developmental delay (n = 0), Duane's retraction syndrome (n = 3), partial nerve palsy (n = 0), or visual acuity ≤ 20/200 PD in 1 eye (n = 1).
†Two patients underwent further recession of previously recessed MR.

RESULTS

The median age of the patients was 5.1 years (range 12 months to 14 years). The mean age of 6.3 years for the patients for whom adjustment was not indicated was not significantly different from the mean age of 7.4 years for the patients who did need an adjustment ($t_{(59)} = 1.32$, $P = 0.19$).

Tables 2 and 3 list the results for exotropia and esotropia, respectively, based on the type of surgery. Each table further categorizes the results based on the number of patients for whom adjustment was recommended; the number of patients who were considered to have successful outcomes, which we defined as being within 10 prism diopters (PD) of orthophoria at the final postoperative visit; and the number of patients who had undergone previous surgery or ≤ 1 of the following pre-existing conditions: marked developmental delay; Duane's retraction syndrome; partial nerve palsy; or visual acuity ≤ 20/200 PD in 1 eye.

At their final postoperative visit, 54 of 61 patients (88%) were within 10 PD of orthophoria. Of the 39 patients who were not adjusted, 35 (90%) were successful. Of the 22 patients who were adjusted, 19 (86%) were successful. The success rate of the operation did not differ statistically between the patients who needed an adjustment and those who did not ($X^2_{(1)} = 0.16$, $P = 0.69$). The success rate of the 6 types of operations (bilateral lateral or medial rectus recession, lateral or medial rectus recession, or recession/resection operations for esotropia and exotropia) did not vary significantly ($X^2_{(5)} = 6.99$, $P = 0.22$).

Eight patients with exotropia were initially undercorrected and underwent an adjustment. Three of the 8 were within 5 PD of orthophoria at their final postoperative visit, and all 8 of the patients were within 10 PD of orthophoria at their final postoperative visit. Five patients with exotropia were initially overcorrected and underwent an adjustment. On the final postoperative visit, 4 of the 5 patients were within 5 PD of orthophoria, and 1 patient was still overcorrected by 12 PD despite adjusting the lateral rectus from 7.5 to 5.0 mm. This patient had a history of a shunt placement for hydrocephalus and a marked developmental delay, which may have contributed to the unpredictable outcome. Seven patients with esotropia were initially undercorrected and underwent an adjustment. Four of the 7 patients were within 5 PD of orthophoria, and 6 of the 7 were within 10 PD of orthophoria at the final postoperative visit. One patient developed an overcorrection after surgery of 12 PD exotropia. Only 1 child with esotropia was initially overcorrected but was orthophoric at the final postoperative visit.

Table 4 shows the amount of postoperative drift for each type of operation. The amount of postoperative varied significantly depending on which operation was performed ($F_{(5)} = 5.68$, $P < .001$). The amount of postoperative drift did not, however, differ significantly whether or not the patient underwent an adjustment ($t_{(59)} = 0.84$, $P = 0.40$).

TABLE 4. Average Postoperative Drift

Diagnosis	Type of Operation	No. of Patients	Postoperative Drift (PD)
Exotropia	Bilateral LR recess	11	9.4 exophoric
	Recess 1 LR	16	4.8 exophoric
	LR recess, MR resect	5	10.6 exophoric
Esotropia	Bilateral MR recess	20	1.1 exophoric
	Recess 1 MR*	7	1.9 exophoric
	MR recess, LR resect	2	4.0 esophoric
All groups		61	4.2 exophoric

*Two patients underwent further recession of previously recessed MR.
LR: lateral rectus; *MR:* medial rectus; PD, prism diopters; *recess:* recession; *resect:* resection.

Children with previous surgery or pre-existing conditions were not more likely to undergo an adjustment compared with children without these pre-existing conditions ($X^2_{(01)} = .01$, $P = 0.90$). Overall, however, the children with previous surgery or a pre-existing condition were more likely to have unsuccessful final outcomes ($X^2_{(01)} = 5.36$, $P < .05$). The type of operation also did not significantly determine whether the patient would be adjusted ($X^2_{(5)} = 5.58$, $P = 0.35$). Finally, patients who had a preoperative strabismus angle > 30 PD were not significantly more likely to undergo an adjustment than patients who had a preoperative measurement ≤ 30 PD ($X^2_{(1)} = 0.001$, $P = 0.97$).

DISCUSSION

Based on our review of the literature, this is the first description of an adjustable-suture technique that requires no further manipulation of the eye if no adjustment is needed. This modification makes the technique particularly advantageous for using adjustable sutures in children. Previous studies have reported the use of adjustable sutures only on older children who could undergo manipulation of the eye while awake.[4,5] Based on our review of the literature, our study is also the first to describe using adjustable sutures in children < 7 years old.

The use of standard adjustable sutures requires the manipulation of the conjunctiva while the patient is conscious. The patient is frequently uncomfortable and experiences nausea, pain, and occasionally a potentially dangerous vasovagal response that makes postsurgical care difficult.[6] Techniques have been developed to make the manipulation after the primary surgery easier. Several investigators have described a technique in which the postoperative adjustment takes place in the operating room immediately after surgery with the use of conscious sedation[7-9]or under topical anesthesia.[10] Delaying the adjustment until the next day can decrease the nausea associated with adjustment.[11] Using subtenon ropivacaine has been described to lessen the pain of manipulation.[12] Coats[13] described a novel all-or-nothing rip-cord technique of adjustment. Saunders and O'Neil[14] described a method of tying the knot during the primary surgery so that the knot did not have to be tied for the patients who did not require adjustment. These patients, however, still had to undergo further manipulation consisting of trimming and then tucking the exposed pole sutures underneath the conjunctiva. The major advantage of our method is that children who did not require adjustment also did not require postsurgical manipulation of any kind. This is a major advantage because the majority of patients undergoing adjustable sutures do not require adjustment.[5,11-15]

Our results compare favorably with other reports on the use of adjustable sutures in children. In our study, 88% of our patients were within 10 PD of orthophoria at their final postoperative visit. This compares with a success rate of 76 % and 74%, respectively, for Dawson et al[4] and for Chan et al.[5] Only Chan et al[5] subdivided results into esotropia and exotropia. In our study, 86% of children with esotropia were within 10 PD of orthophoria at their final postoperative visit, whereas Chan et al[5] reported a 76% success rate. In our study, 91% of children with exotropia were within 10 PD of orthophoria at their final postoperative visit, whereas Chan et al[5] reported a 73% success rate. The lower overall success rate of Dawson et al[4] and Chan et al[5] could be explained by the greater complexity of the strabismus of their patients, with 60% and 53% having had previous strabismus surgery, respectively. Only 10 of our patients (16%) had undergone previous strabismus surgery. These patients, however, did very well: 8 of 10 (80%) achieved alignment 10 PD within orthophoria.

In an attempt to have as unbiased a study as possible, our study looked at all 61 consecutive patients who underwent strabismus surgery for horizontal deviations; therefore, the study included a diverse population of strabismus patients. Examining the data from two major subgroups in our study—ie, patients with intermittent exotropia who did not have previous surgery or a pre-existing condition and patients with essential (nonaccommodative) esotropia who also did not have previous surgery or a pre-existing condition—may give a better indication of the usefulness of this technique.

Seventeen patients had intermittent exotropia with no previous surgery or pre-existing condition. Five of these patients underwent an adjustment. All 17 patients were within 0 to 10 PD of exotropia at their final postoperative visit; average follow-up was 5 months. This compares favorably with reports of up to 38% of patients needing reoperation for strabismus for exotropia.[16,17] However, our patients have been followed-up for a relatively short time, and our results will most likely be less successful over time.

Fourteen patients had an essential esotropia with no previous surgery or pre-existing condition. Three of these patients underwent an adjustment. Thirteen of the 14 patients (93%) were within 0 to 10 PD of esotropia at their final postoperative visit, with an average follow-up of 6 months and 2 weeks. One of the 14 patients developed an

overcorrection of 12 PD of exotropia. This compares favorably with even the relatively high success rate of the Prism Adaptation Study,[18] which reported a success rate of 89% at the 6-month postoperative visit. Patients did undergo on average a longer follow up in the PAT study, however, and our results may be less favorable with longer follow-up.

The question of whether the use of adjustable sutures improves postsurgical results cannot be definitively answered without a prospective study with a randomized control group. It is possible that our results were caused by other factors such as the youth of the patients. However, analysis of the results in children who did undergo adjustment for initial undercorrections and overcorrections suggests, but does not prove, that the majority of children who underwent adjustment did benefit. Of the 8 patients with esotropia who underwent an adjustment for an initial undercorrection, there was an average of 10 PD of shift toward orthophoria immediately after surgery, with only 1 patient developing an overcorrection. The 1 child with esotropia who underwent an adjustment for an overcorrection was orthophoric at the last follow-up visit. Of the 8 children with exotropia who underwent an adjustment for an undercorrection, there was an average of 11 PD of shift toward esotropia immediately after adjustment. All 8 were within 10 PD of orthophoria and had no overcorrections at their final postoperative visit. Of the 5 children who underwent an adjustment for an initial overcorrection, 4 were within 4 PD of orthophoria at their final postoperative visit. Overall, 19 of the 22 (86%) patients had excellent postoperative results as defined as being within 0 to 10 PD of exotropia for patients with exotropia and within 0 to 10 PD of esotropia for patients with esotropia.

One of the major advantages of this technique is that adjustable sutures can be used on young children. Based on our search of the literature previous to our study, only cooperative children age ≥ 7 years old have been described as being able to undergo adjustable sutures.[4,5] In our study, 49% of the children were < 7 years old. In those with esotropia, 69% of the children were < 7 years old; 52% of the children were < 5 years old. The youngest child with esotropia was 12 months old. Early surgery, especially before the age of 24 months, has been associated with increased binocularity and better overall results in children with esotropia.[19,20] The ability to use adjustable sutures on young children may be one of the most important benefits of this modified technique. Although all 3 children who were < 24 months were orthophoric on their final postoperative day, our sample is too small to claim useful conclusions. However, 1 of these children, who was 16 months old at the time of surgery, illustrates the potential benefit of being able to use adjustable sutures in such a young patient population. This child was significantly undercorrected with an esotropia measuring 15 PD for distance immediately after surgery. After undergoing adjustment, the child was orthophoric and has remained so as of his last follow-up visit 8 months after surgery.

Investigators have suggested that optimal candidates for adjustable-suture techniques are patients with pre-existing conditions such as reoperations, incomitant strabismus such as Duane's retraction syndrome, paralytic strabismus, sensory anomalies such as visual acuity $< 20/200$ in 1 eye, and significant developmental delay, because surgical outcome is less reliable in such patients.[21] Interestingly, in our study the children with previous surgery or pre-existing conditions were not more likely to undergo an adjustment compared with children without these pre-existing conditions ($X^2_{(01)} = .01$, $P = 0.90$). However, the final postoperative result in these patients was, as found in the previously cited studies, less successful than in patients without these conditions ($X^2_{(01)} = 5.36$, $P < .05$). In our study, then, the initial alignment in these patients with pre-existing conditions after surgery was similar to those without pre-existing conditions, but the patients with pre-existing conditions were more likely to drift to a position > 10 PD of exotropia or esotropia.

One major disadvantage of our technique is that it requires a second anesthetic. This not only adds the risk of another anesthetic but can also be difficult to schedule, especially if only 1 or 2 operations are being performed and another surgeon is waiting to use the operating room. In our operating room, we have the advantage of being able to schedule the entire day (4 to 7 patients) for pediatric ophthalmic procedures. We schedule the patients who undergo surgery with adjustable sutures first to allow sufficient time between the initial surgery and the possible adjustment. The additional time is not difficult to schedule because the adjustment usually requires only 20 minutes total time in the operating room. Because the child already has an intravenous line, he or she can be placed under anesthesia without having to be induced with inhalation gases.

Another potential disadvantage of this technique is the use of an additional scleral pass to bury the excess suture. However, this second scleral pass accomplishes 2 things. First, the sutures can be tied to prevent slippage of the muscle. Second, it prevents postoperative inflammation of the exposed sutures. We found in an earlier technique that not burying the suture but simply covering the conjunctiva caused inflammation in $> 10\%$ of children. None of the patients in our study developed an unusual inflammatory response or suture granuloma in the eye that underwent an adjustable suture. The postoperative appearance of the eyes with and without adjustable sutures was similar.

In summary, the data presented show that children undergoing strabismus surgery with this modified technique obtain good results; there are few reoperations and a high overall success rate. The use of the technique is not associated with an increased inflammatory response in the area of surgery. There were no complications such as slipped muscles or postoperative infections using this tech-

nique. For those children who underwent an adjustment, the majority had an improved postoperative result compared with the predicted result without an adjustment.

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