Adjustable sutures in children

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SUMMARY Although adjustable sutures are considered a standard technique in adult strabismus surgery, most surgeons are hesitant to attempt the technique in children, who are believed to be unlikely to cooperate for postoperative assessment and adjustment. Interest in using adjustable sutures in pediatric patients has increased with the development of surgical techniques specific to infants and children. This workshop briefly reviews the literature supporting the use of adjustable sutures in children and presents the approaches currently used by three experienced strabismus surgeons. (J AAPOS 2014;18:278-284)

Although adjustable sutures are frequently used in adults, few strabismus surgeons use them routinely in children. The rationale for not using adjustable sutures is understandable—children are difficult to evaluate in the hours after surgery, and the procedure adds time and stress to strabismus surgery while increasing the logistical complexity of postoperative management. Add to that a more fundamental skepticism of adjustable suture surgery held by many (especially those who lack experience using the technique), and the result is that only a handful of strabismus surgeons currently use adjustable sutures in children. While no randomized, controlled trials compare adjustable sutures with fixed sutures,[1] we lack such evidence for most of our surgical approaches, including whether or not to perform strabismus surgery at all, and there is strong retrospective evidence (see below) that adjustable sutures can improve the outcomes of strabismus surgery.

The purpose of this AAPOS workshop is to share our decades of experience performing adjustable sutures in children to assist surgeons who are considering adopting the technique. The workshop first provides a brief overview of the current published results of success using adjustable sutures in children. It then provides varied perspectives on the technical aspects of the approach used by each of the authors in his own words, as transcribed during their AAPOS workshop.

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Results of the Adjustable Suture Approach in Children

A number of recent reports and review articles have addressed the topic of adjustable sutures, including a review by Nihalani and Hunter[2] and by Engel.[3] Only one published study—based on Dr. Guyton's experience—has compared a single surgeon's results using adjustable sutures with a control group of children operated on without adjustable sutures.[4] That study was a retrospective review of horizontal muscle surgery in patients ≤10 years of age. A group of 298 patients treated with adjustable sutures was compared with 98 historic controls operated on before Dr. Guyton switched to adjustable suture surgery in children in 1994. Satisfactory alignment was defined as $\leq 8^{\Delta}$ of strabismus at 3 months' follow-up. In that study, 79% in the adjustable group achieved satisfactory alignment versus 64.5% in the nonadjustable control group ($P < 0.01$.) Other studies have also shown a high success rate. Engel and Rousta[5] reported an 88% success rate with a median follow-up of 19 weeks (range, 6-54 weeks). Nihalani and colleagues[6] described similar success rates. In fact, most published studies of adult and pediatric strabismus surgery where adjustable sutures were compared with a fixed-suture control group showed improvements of 14% to 33% in success rates or reoperation rates[2] in the adjustable suture groups (Table 1).

Three Adjustable Suture Techniques Used in Children

Dr. Guyton

Since 1981 I have performed adjustable suture surgery on adults, and I have routinely used the approach in children since 1994. In the early days of adjustable sutures we anticipated that it would be an unpleasant experience for the patient; however, with practice, our approach became

Table 1. Published clinical trials comparing outcomes of adjustable with nonadjustable sutures in children

Author	N	Reoperation rate		Success rate	
		Adjustable	Nonadjustable	Adjustable	Nonadjustable
Kraus and Bullock (1993)[7]	36	11%	29%	77%	46%
Tripathi et al (2003)[8]	443	9%	27%	96%	63%
Awadein et al(2008)[4]	396	-	-	79%	65%
Budning et al (2010)[9]	304	9%	27%	-	-

FIG 1. Q-tip test. A cotton-tipped applicator or similar material is applied to the unanesthetized lateral conjunctiva while the patient looks away.

more sophisticated, and we became comfortable carrying this over to select older children who seemed most likely to cooperate for postoperative adjustment. We could tell who was most likely to be able to cooperate by performing some quick tests. For example, if we touched the bare sclera with a corner of a fragment of facial tissue and the child did not flinch, he or she would do fine (Figure 1). If you simply examine how children react to the eyedrops, you can predict what their behavioral response will be after the surgery. Now with better anesthetics, including propofol, we are able to use adjustable sutures in children as young as 6 months regardless of how cooperative they are for the actual adjustment. Only rarely will they not cooperate for the postoperative assessment by refusing to open their eyes (less than 1% of cases).

Which muscles do I adjust? All of them, except when weakening the inferior oblique muscle, because it just appears floppy and does not respond to the adjustment. For example, an adjustable superior oblique suture spacer is shown in Figure 2. Note, however, that unlike most muscles, which require the patient's looking away from the muscle during the adjustment, in the case of the superior oblique muscle, the patient must look *up* in order to loosen the tendon enough to gain access to the sliding noose knot (Figure 2C).

Which procedures do we adjust? You may adjust any of them, including recessions, resections, tucks, Harada-Ito procedures, transpositions, and lower lid suspensions.[10-13] The only procedure where I do not adjust is the posterior fixation suture. Although I am aware that there have been adjustable procedures developed for this, I am not entirely sure how well they work.

For the procedure itself, when I first began operating, I used local anesthesia for adults, and while this worked well for two decades, the trouble is that we had to wait 5-6 hours for the anesthetic to wear off. Now I prefer general anesthesia for both adults and children, not only because you can perform the suture adjustment just an hour after surgery but also because you can judge the position of the eyes better at the beginning of surgery, and forced ductions are more reliable. I do not have much experience with using topical anesthesia for adjustable suture surgery.

The technique I like best for adjustable sutures is the cul-de-sac approach. I learned early on that it is more efficient because it is faster and the knot is buried. Also it is the best for postoperative comfort and for less scarring, but it requires a good assistant. The Guyton small incision muscle hook (Katena, Denville, NJ), has made my life easier because I can do these procedures with a small incision, without tearing the conjunctiva (Figure 3). It is similar to a Jameson muscle hook but includes an extra bend (Figure 3A). This hook facilitates strabismus surgery through a small cul-de-sac incision, so that the suture ends are better covered with more comfort. The conjunctiva never needs to stretch more than the distance between the ball and the second bend in the hook. When you bring the ball out, you do not have to stretch the tissue very far (Figure 3B), and this keeps the incision small and helps it heal faster.

The muscles are then isolated and secured. I use the S-28 needle to secure the muscle; I like the 18″ length to have more suture to use for the adjustable portions. I always hang these muscles back from the original insertion, even for a resection, where I will resect an extra 2 mm and then hang the muscle back 2 mm to allow for adjustment in either direction. Then I put a sliding noose on the suture. I also add a scleral traction suture.

My other panel members have found ways to bury their sutures, but I have not had that need. I do not like that extra suture left behind, so we developed a removable sliding noose to take away all of that extra knot and noose material after the suture adjustment. The sliding noose is a 6-0 polyglactin 910 clove hitch with three slip knots. After adjustment, the noose is pulled sideways and pops off. When deciding where to leave the noose, I anticipate that removing it will yield 1.5$^{\Delta}$ of loosening. I have described this removable noose in detail elsewhere,[14] along with an online video illustrating how it is tied, adjusted, and removed.

I always go back to either adjust or tie off, and with young children that means placing them back under

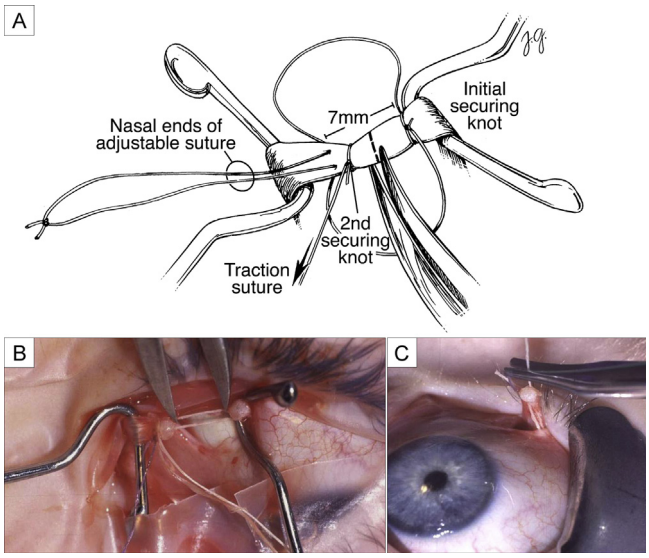

FIG 2. Adjustable superior oblique suture spacer. View of the left eye from below. A, Following exposure of the superior oblique tendon and placement of initial securing suture knot (doubled-armed 6-0 polyester suture), the nasal ends of the adjustable suture are placed through the superior oblique tendon 7 mm farther toward the trochlea, with an additional securing suture knot placed proximal to this point, leaving one end from this knot long. The tendon is transected. B, The sutures are adjusted to leave a desired separation from 2 to 8 mm. C, For bedside adjustment the patient is initially asked to look straight ahead and then up, to allow easiest access to the suture. Once adjustment is complete, the adjustable suture is tied off and trimmed. Modified, with permission, from Goldenberg-Cohen et al. (2005).[11]

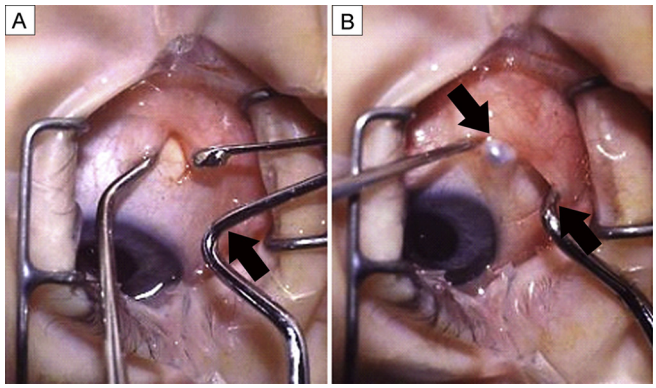

FIG 3. Guyton muscle hook. A, Maximum extent of conjunctival stretching is between ball of hook and arrow. B, Conjunctiva lifted up and over ball of hook demonstrating smallest potential incision size (between arrows).

anesthesia. While they are under anesthesia, I have a chance to do a finer adjustment. I adjust about 65% of my patients, whereas my colleagues may perform this on fewer occasions because they feel that if it looks good then there is no need to put the child back to sleep to adjust.

When do I adjust? With adults I adjust at the bedside at the end of the operative day, but with children I adjust in between subsequent cases (and without putting them back to sleep if they are cooperative.)

What are the success rates in children? I began using adjustable sutures routinely in children in 1994. We compared our success rates with nonadjustable sutures before 1994 with those using adjustable sutures beginning in 1994, tabulating successive horizontal adjustable cases. Pre- and postoperative measures in straight-ahead gaze in the distance were examined, with postoperative measurements at approximately 3 months postoperatively. Surgical success was defined as deviations $\leq 8^{\Delta}$. A total of 64% were adjusted; 20% of the patients received topical proparacaine, and 80% received intravenous propofol anesthesia. As noted above, our results showed better outcomes in the adjustable group.

What happens if children do not open their eyes? In my entire career I have had only 4 children who simply would not open their eyes. There are some techniques that usually work. The one that works the best is to hold the child in the air, upside down, and feign dropping him or her (Figure 4). Most living things open their eyes when they sense they are being dropped on their face!

Where do we target the adjustment? For exotropia we leave the patient straight, fusing at near, but overcorrect in the distance, with double vision beyond 5-6 feet. With esotropia we aim for exact alignment in the distance, and with hypertropia we slightly undercorrect the patient in straight-ahead gaze.

In conclusion, modern adjustable suture techniques have improved over the years and are may be used in children as well as adults. Practically all strabismus procedures can be adjusted, and I prefer removing the sliding noose to facilitate both comfort and healing. Granted, there are some roadblocks with adjustable sutures. One is the long learning curve. It takes my fellows over 6 months to become proficient with this technique. It requires training and experience, and I would not expect even the best surgeons to become comfortable with adjustable sutures right away. Also more time is required, about 3-5 minutes intraoperatively and 15-20 minutes for adjustment, so it takes time when you could be performing another case. Anesthesiologists may also offer resistance because they are not used to putting children back to sleep in the recovery room. Also one has to consider that the cost of the procedure is higher than that for a nonadjustable approach. On the other hand, the concept of fine tuning the surgery is attractive, and the surgeon may experience less anxiety knowing that there will be a second chance to obtain the desired alignment. All things considered, the results are better. While we do not always know where to leave the muscle, adjustable sutures provide a way to protect the patient from unexpected unpleasant results.

Finally, remember the golden rule: do unto others as you would have them do unto you. If your child were to have such surgery, would you like the option of fine-tuning the result? Think about that when you are performing strabismus surgery on a young child.

FIG 4. Encouraging an infant to open his eyes. (This 1-day-old infant has not had strabismus surgery.) Feigning dropping the child will reliably induce eye opening.

Dr. Hunter

I would like to focus first on the specifics of how to perform the procedure, including the procedure itself, assessment of a child in recovery room, and the sedated adjustment, and second on the results we and others have obtained.

I do not use adjustable sutures in all of my pediatric strabismus cases. If it is a straightforward case with consistent measurement then I do not feel that there is a need to add the extra logistic complexity of the postoperative assessment and adjustment. But in complex cases, including reoperations and incomitant strabismus, it is a tremendous aid for me to be able to structure my surgical planning knowing that I will have the option to adjust.

My basic approach to adjustable sutures starts out the same as Dr. Guyton's, with a standard hang-back recession. I apply a standard (nonremovable) sliding noose, and you will see in a moment why I do not remove the noose—I refer to it as the "short tag noose." I have produced videos of this procedure, and they are available online for no charge[15] and with two textbooks.[16,17] Briefly, I tie the noose sutures to each other with an overhand knot, leaving the noose about 5 mm long with no whiskers at the end of the knot. Once the sliding noose is positioned where I want it, I tie these sutures to each other exactly 5 mm away from the position of the sliding noose, leaving 2 mm whiskers on the pole sutures. By leaving longer whiskers on the pole sutures and shorter ones on the noose, it is easier to figure out which strings need to be pulled at the time of suture adjustment. Also, the longer whiskers make it less likely that the pole sutures will untie and potentially allow the sliding noose to slip off during adjustment. By tying the pole sutures exactly 5 mm from the noose, I am able to tell at the time of suture adjustment exactly how far I have moved the slip knot. At the end of the case I tuck all of the sutures under conjunctiva. I delay dictation of my operative report until after the suture adjustment so that future surgeons will know exactly where the muscle ended up.

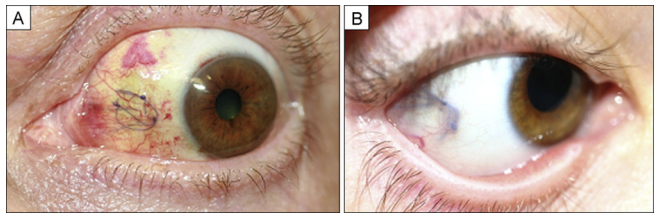

FIG 5. Postoperative appearance of short-tag noose sutures. A, 1 week after surgery (adult). B, 1 month after surgery (11-year-old child). The sutures are visible but not causing discomfort.

There are two great advantages of the short tag noose approach. First, if the child does not require suture adjustment, there is no need for a second sedation. Second, if there is a change in the first week after surgery, it is possible to readjust—in the office for adults, or with a 5-minute mask sedation for children. As long as the sutures are all buried under conjunctiva, they are not going to bother the patient, either in the short term or the long term. The extra suture material has not been an issue for my patients, although they remain visible under conjunctiva until they finally dissolve 2 months later (Figure 5).

We send the child to recovery with orders for nothing by mouth. I wait a minimum of one hour after surgery before assessing the child in the recovery room. This generally means that I will perform another surgery to allow for time to pass. I will then assess the child between the second and third (or third and fourth) case of the day. If it is the last case of the day, I wait a minimum of one hour. However, if the child cannot sit up on his or her own without leaning against a parent or the bed, then it is still too early to assess, and I have to return later.

Often a child is remarkably cooperative for postoperative assessment, but as Dr. Guyton pointed out above, there are times when a child seems inconsolable and an assessment may appear at first glance to be impossible. Indeed, it is not unusual for it to take 20 minutes to calm a fearful patient, but most of the time, eventually, I get my way. If the child is sitting up with eyes open, I don't need to use eyedrops, but if he or she is already crying or fussy, I will add some proparacaine right away (despite the temporary exacerbation of the fussiness) because I know it will feel better if they open their eyes with topical anesthetic on board. I always have the patient sit up on his or her own with legs dangling over the edge of the bed—not curled up and slumping against mommy. I speak directly to the child by name. Sometimes whispering helps. A typical script for a crying child is something like this (all said while the child is sitting up): "Joey, this is Dr. Hunter. Joey… shhh… Joey, listen to me. Joey, this is Dr. Hunter, now listen, Joey, do you want to go home? Yes, you want to go home? Good, because I want you to go home too, and I am the *only one in the hospital* who can let you go. But you need to help me. Joey, Joey… shhhh… Joey, I need

to have a look at your eyes, and once I see them, then you can go home. Okay? Now just blink your eyes open and look at my toy. Good!" Most of the time such coaxing is not necessary, and the child will understand what needs to be done and cooperate without much fuss.

If a child does need an adjustment, I will summon the anesthesiologist to administer propofol via the existing intravenous line. At Boston Children's Hospital we have collaborated with nursing and anesthesia to develop a formal protocol for sedated suture adjustment (e-Supplement 1, available at jaapos.org). We overcame some initial resistance to this protocol by emphasizing that avoiding future procedures was in the patient's best interest. During the adjustment, oxygen and a mask are available, with the anesthesiologist at the head of the bed, me on one side and an assistant on the other side. The anesthesiologist administers 3 mg/kg intravenous propofol. I add additional topical anesthetic and insert a lid speculum. Often there will be some reaction to either the eyedrops or the speculum, and an additional 1 mg/kg of propofol is administered. It is not unusual to go step by step up to 11 mg/kg in some patients. Once the child is sedated and not reacting to manipulation of conjunctiva, I commence the adjustment.

Videos of the sedated adjustment are available on our webcast[18] and with our book chapters.[15,16] It can be a little tricky to find the sutures in some cases because I don't use a conjunctival traction suture, but with the child sedated, that is never more than a nuisance. If I want to advance the muscle (Figure 6A), I pull all of the sutures (and the muscle) forward, grasping the pole suture with one set of needle holders and the sliding noose with the other, and then cinch the sliding noose toward the muscle to reduce the recession. If I want to increase the recession (Figure 6B), again the first step is to pull the sutures forward, but in that case I grasp the pole sutures behind the noose and slide the noose away from the muscle. I then measure the amount of adjustment by measuring the distance from the end of the pole suture to the noose—recall that I set that number at 5 mm during surgery. For example if I want to increase a recession by 2 mm, the distance from the pole suture knot to the sliding noose will be reduced from 5 down to 3 mm.

I have only had to adjust about 20% of children, meaning that 80% go home without the need for secondary intervention. On occasion—about 2-3 times a year—I will reverse an undesirable result up to a week after surgery. This can be done by booking 15 minutes in the operating room for a sedated suture adjustment.

Because I do not tie the knot, I am often asked how often the noose slips during the postoperative period. This has only happened to 2 patients in the last 12 years (both adults), and both were immediately symptomatic, so I was able to bring them back to the office, retighten the noose, and readvance the muscle. It has been more than 7 years since the last muscle slipped.

To summarize, the short tag noose approach is, in my opinion, an ideal option for performing suture adjustment in children. It allows full and precise adjustment—either advancement or recession. Yet it is a true safety net, only used when required but invaluable in those cases.

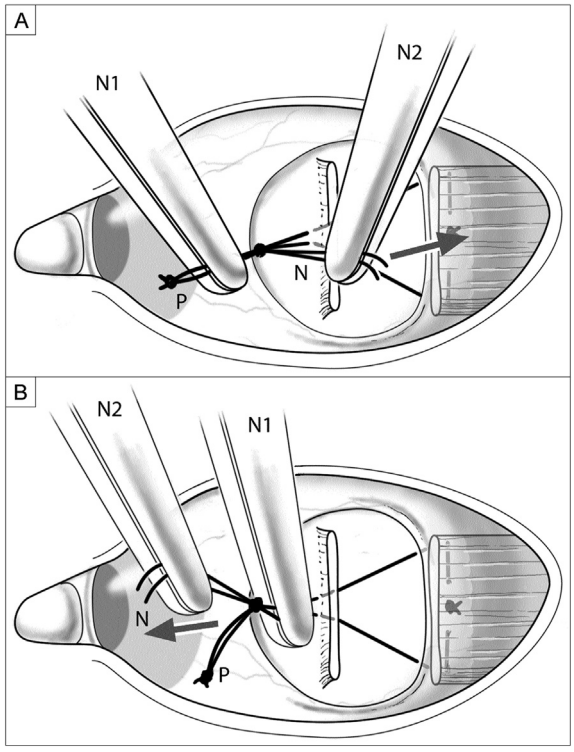

FIG 6. Short tag noose adjustment. A, reducing the recession by moving the sliding noose closer to the muscle; B, increasing the recession by moving the sliding noose away from the muscle. *N1*, needle holders securing pole suture (*P*); *N2*, needle holders securing noose (*N*). Reproduced/modified with permission from Nihalani et al (2009).[6]

Dr. Engel

My technique differs a little from those of Drs. Hunter and Guyton in the way that I bury the sutures. Like Dr. Guyton, I am a little more concerned about leaving the extra suture material behind. I ensure that extra suture needed to adjust the muscle is buried in the sclera so it doesn't irritate the conjunctiva.

My basic technique, which I use for the superior, inferior, and medial rectus muscles, is summarized in Figure 7A. I use the 6-0 polyglactin 910 suture for the noose and cut those short, as does Dr. Hunter. If you are concerned about slippage of the muscle, you can make another small scleral pass parallel to the other one so this suture will not move. If you have to adjust, you simply remove the affected sutures. In this sense it is just like having another hang-back suture.

I do not use a noose at all for the lateral rectus muscle because I have had some conjunctival reactions to the sutures. Also, while the other rectus muscles seem to remain taut after recession, the lateral rectus muscle just sits there, making it seem more susceptible to vertical migration during healing. To address these concerns, I developed a hemi-hang-back, no-noose technique (Figure 7B), in which there

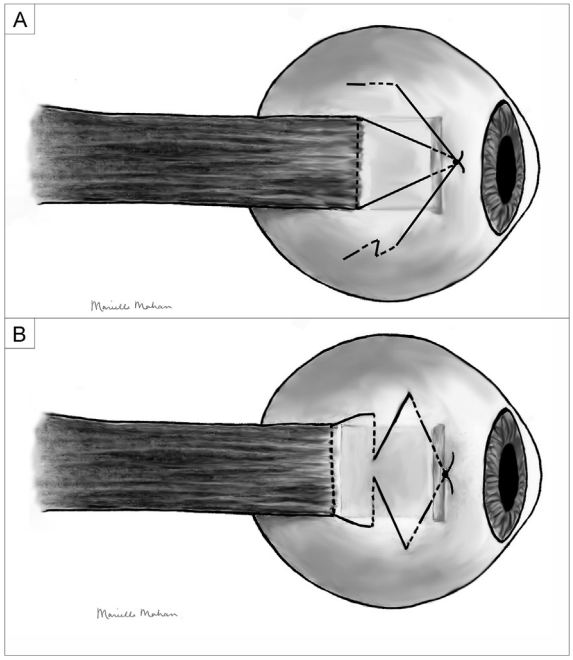

FIG 7. Adjustable suture approaches used by Dr. Engel. A, Sliding noose method for medial, superior, and inferior rectus muscles. A noose is placed around the two pole sutures, which are buried under the conjunctiva with short scleral passes. B, Hemi-hang-back technique for the lateral rectus muscle. Additional scleral passes are made and buried underneath the conjunctiva. Reproduced with permission from Engel (2012).[3]

is no suture knot, the muscle can be advanced or recessed further, and there is less concern about vertical migration. Let's say, for example, that I want to perform an 8 mm recession of the lateral rectus muscle. I perform a 5 mm recession and pass the sutures as for a nonadjustable case. Then, without tying the sutures, I place two additional scleral passes and bring this extra suture (the extra suture that I will unbury if I need to adjust) up to the original site of insertion. Then I let the muscle hang back 3 mm to complete the 8 mm recession, which will allow me to advance or recess the muscle as required.

At the end of the case I close conjunctiva with 8-0 polyglactin 910 sutures with the knots buried because the children seem to be more comfortable with that. I also inject 1% preservative-free lidocaine under the conjunctiva.

Postoperatively my plan is to wait longer than Dr. Hunter because I want the patient to have plenty of time to sleep and be comfortable before adjustment. I like to wait at least 2-3 hours after surgery and often about 4 hours. This allows me to review the progress and maximize the accuracy of my postoperative measurements. The patient should be able to open his or her eyes without assistance and look at a fixation target for approximately 5-10 minutes before I decide whether to adjust. Do not hold the eyes open with your fingers to evaluate alignment; the assessment will not be accurate. If possible, perform a cover test.

I perform the adjustment in the operating room because it is helpful to have the anesthesiologist present if the patient

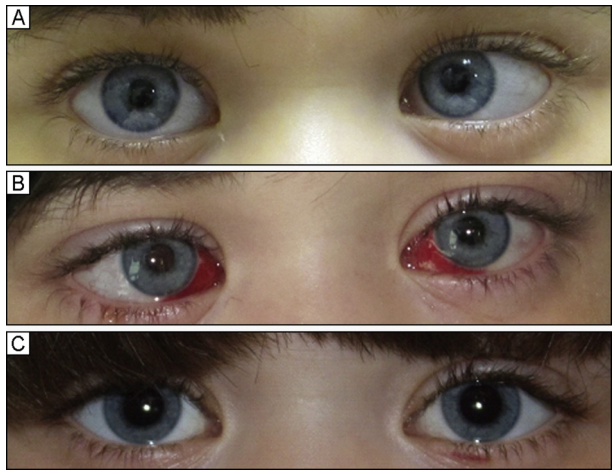

FIG 8. Adjustable esotropia surgery for a 6-year-old child. A, Preoperatively, the patient had a 35^{Δ} esotropia. She underwent bilateral medial rectus recessions of 5 mm, with the right medial rectus muscle placed on an adjustable suture. B, At suture adjustment 4 hours postoperatively, she was significantly undercorrected, with an esotropia of 20^{Δ} at distance and 25^{Δ} at near. At suture adjustment, the left medial rectus muscle was recessed an additional 2.0 mm for a total recession of 7 mm. C, 6 months after the surgery the patient had excellent alignment and no visible conjunctival scarring.

needs adjustment or has to be sedated. If you need intravenous sedation, then I agree with Drs. Guyton and Hunter that you need more than you think. I find that if I use tetracaine, there seems to be less need for intravenous medication.

To adjust the sliding noose on the inferior, superior, and medial rectus muscles, I place locking forceps at the insertion and then I unbury the extra suture to reposition the noose. After the muscle has been adjusted, I tie the pole sutures, trim the knot, and close the conjunctiva with the 8-0 polyglactin 910 sutures. To adjust the lateral rectus muscle using the hemi-hang-back technique, I snip the knot located at the original insertion (Figure 7B) and unbury the extra suture so that I have 6–7 mm of suture with which to either advance or recess the muscle. After advancing or further recessing the muscle, I tie the sutures, trim the knot, and close the conjunctiva with 8-0 polyglactin 910 sutures. I try to be meticulous about conjunctival closure and have recently changed to only using 8-0 polyglactin 910 because the 7-0 chromic will sometimes break, presumably by the force of the child rubbing the eyes postoperatively. I feel this almost eliminates suture granulomas. On average, I adjust about 30% of the time, which is slightly more than Dr. Hunter, but less than Dr. Guyton.

An example of the power of using adjustable sutures is illustrated in Figure 8. In this case, the patient had a significant and unexpected undercorrection 4 hours after bilateral medial rectus recessions of 5 mm for an esotropia of 30^{Δ}. By increasing one medial rectus recession at suture adjustment she ended up with an excellent postoperative result. I am convinced she would have required a second operation had I not had the opportunity to adjust.

Conclusions

Adjustable sutures allow for refinement of the postoperative alignment that is most helpful in cases where the desired outcome of surgery has clearly not been attained. A variety of approaches may be used when performing adjustable sutures in children. Pediatric strabismus surgeons who wish to add adjustable sutures to their armamentarium should, with some persuasion and persistence, be able to convince anesthesia and nursing leadership at their hospitals to safely allow for this option.

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