New and complex strabismus surgeries: exciting times!

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Strabismus surgeries have, in recent times, progressed at a rapid rate, with the introduction of a multitude of remarkable techniques that have defied the rules of classic surgery. With the advent of newer imaging modalities, and a better understanding of disease pathophysiology, surgical techniques are more targeted toward the specific muscles involved and its pathology. This article endeavors to outline some of the newer complex surgeries, their effectiveness and the basis behind them.

Surgeries for “Heavy Eye Syndrome”
“Heavy eye syndrome” or “myopic strabismus fixus convergence”, is an acquired restrictive strabismus occurring in patients with pathologic myopia. Patients often manifest extreme esotropia, hypotropia and restricted ocular motility. Simple resections and resections have a limited role in this entity.

What’s new?
After the advent of orbital imaging, MRI studies showed supero-temporal prolapse of the elongated posterior portion of the eyeball, leading to an inferior shift of the lateral rectus (LR) and nasal shift of the superior rectus (SR) (Figure 1). Based on this new-found explanation, there was a paradigm shift in surgical techniques, which aimed more at vector mechanics, rather than simple muscle strengthening/weakening.

Loop myopexy
In 2001, Yokoyama first proposed a new surgical idea, when he suggested to union the LR and SR together, and use it as a muscle pulley to push the herniated eyeball back into the muscle cone.

Technique
This technique is performed by isolating both the SR and LR muscles through either a superotemporal fornix based conjunctival incision or a limbalperitomy. Once the muscles are isolated, a 5-0 non-absorbable suture is passed through the lateral one-half of the SR and the superior one-half of the LR at ~14–16 mm posterior to the limbus and securely tied. Scleral fixation is not necessary. This eliminates the risk of scleral perforation. This technique can be done either with muscle splitting (e.g. partial Jensen’s) or without muscle splitting.

Other variants of this surgery include scleral fixation and use of type 240 silicone band with Watzke sleeve as a tethering aid instead of suture material. If preoperative forced duction testing (FDT) is positive or if the esotropia is long standing with likely contracture of the medial rectus (MR), recession with the possible use of an adjustable suture can improve outcomes. However, in the absence of these findings, MR recession may be staged for a second surgery.

Muscle transplantation
True muscle transplantation has been proposed for very large angle strabismus patients like heavy eye syndrome, especially when only one eye is planned to be operated upon. This is of value if the FDT shows a tight MR in cases of longstanding esotropia, and can be combined with loop myopexy. Successful outcomes have been reported with >120 PD of esotropia and 40 PD of hypotropia getting corrected to <20 PD esotropia and 20 PD hypotropia after this procedure.

Technique
First the MR is dissected and separated via a fornix incision in the lower nasal quadrant. A non-absorbable 6-0 prolene suture is tied at its muscle insertion. The muscle is then incised from its insertion. Next the LR is hooked. Two 6-0 vicryl sutures are placed away from the insertion as is done in a routine resection of rectus muscle and another pair of 6-0 vicryl placed at the insertion. The muscle is then incised from its insertion and the posteriorly (distally) placed 6-0 vicryl sutures are passed through the original insertion as in a routine rectus muscle resection. The stumps are then cut and placed at the MR site and the distal end of this stump is sutured with the proximal end of MR with the 6-0 prolene already placed on the MR. The now elongated muscle is sutured from the original insertion site of MR as is done in a routine rectus muscle recession.

Paralytic strabismus
Complete muscle palsies, where there is no residual muscle function, do not respond to regular strengthening procedures. Recently, a whole gamut of surgeries has been advocated, with the basis of transposing the other available functioning muscles to serve the purpose of the palsied muscle.

Complete sixth nerve palsy
Vertical rectus transpositions
Vertical rectus transpositions (VRT), coupled with the antagonist muscle weakening, has showed promising results. The main purpose of a VRT is
to allow better rotation of the eye into the field of the palsied muscle by creating tone through the transposed muscles in primary position.\textsuperscript{19}

They also increase the area of binocular vision and shift the binocular field toward the palsied gaze. The transposed muscles do not have active innervation in the field of gaze of the palsy, thereby allowing the antagonist weakening procedure to have better effect.\textsuperscript{20}

The most commonly performed VRT is transposition of the SR and IR to the palsied LR. Rosenbaum describes reattachment of the temporal border of the transposed muscle adjacent to the LR.\textsuperscript{21} The nasal border is reattached following the spiral of Tillaux.

Results
VRT of both vertical recti without antagonist recession or posterior fixation can correct on average 32 PD of esotropia.\textsuperscript{22} The binocular field increases from 25° to 41–51°.

Augmentation of VRT:
1. The partially transposed muscle can be resected symmetrically prior to transposition.\textsuperscript{24–26} This augments the surgery by another 10 PD.\textsuperscript{25}
2. Foster’s posterior fixation suture:
   As originally described by Foster,\textsuperscript{27} a single-armed permanent suture can be placed in the sclera 16 mm from the limbus at superior border of the LR. This suture is then passed 8 mm from the insertion of the SR and IR muscle incorporating ~25% of the transposed muscle. FDT at the conclusion of the transposition with posterior fixation should be free. This can correct an average of 40–55 PD of esotropia in primary and increases the degrees of binocular field to 71°.\textsuperscript{27,28}

3. Mehendale\textsuperscript{29} describes a loop myopexy to close the gap in the transposition procedure in place of the posterior fixation suture. This corrects ~30–35 PD of esotropia for only the SR.

4. Botulinumtoxin:
   Injection of botulinum toxin into the ipsilateral MR at the conclusion of VRT or in the immediate postoperative period\textsuperscript{30,31} can increase the surgical effect to 30–50 PD.

5. To prevent induced torsion:
   The 12 o’clock and 6 o’clock positions on the cornea are marked preoperatively.\textsuperscript{32} Assessing the markings on table following transposition may reveal a torsional shift, which may accompany an induced vertical deviation. Posterior fixation sutures can then be loosened intraoperatively to relieve the torsion created and prevent vertical misalignment.

Nishida’s partial tendon transposition procedure
This is a ciliary vessel sparing surgery, where a 6-0 polypropylene monofilament fiber suture or a 5-0 polyester braided fiber suture is inserted through the temporal muscular margin of each vertical rectus muscle at a distance of 8–10 mm behind the muscle insertion, at approximately one-third of the width from the edge. The sutures should avoid the ciliary vessels in their bite. The scleral bite is then taken at a distance of 10–12 mm behind the limbus at the superotemporal or inferotemporal quadrant, thus transposing the vertical muscles without tenotomy or muscle splitting. The surgical correction by muscle transposition alone ranged from 24 to 36 PD, and that by muscle transposition and recession of the MR muscle ranged from 50 to 62 PD.\textsuperscript{33} (Figure 2a and b).

Figure 1: Shows the inferior shift of LR and nasal shift of SR, increasing the angle between them to 180° (normal angle: 103°).
Complete third nerve palsy
Periorbital fixation of LR
This technique involves complete disinsertion of the LR tendon away from the globe and neutralizing its action by fixing it to the lateral orbital wall.

Technique
After exposing and isolating the LR, blunt dissection is performed to expose the adjacent periosteum ~5 mm posterior to the orbital rim, outside the muscle cone. A 6-0 non-absorbable monofilament suture is used to tag the LR, which is then disinserted from the globe. It is then attached to the adjacent orbital periosteum with two periosteal bites. In a study by Velez et al., this procedure was performed in 7 subjects of complete oculomotor nerve palsy, and their postop deviation was within 12 pd (Figure 3).

Periosteal anchoring of MR
This procedure mechanically pulls the globe away from abduction and fixes the eye in the desired position of alignment with the help of a non-absorbable suture between the MR insertion and the periosteum of the anterior lacrimal crest.

Technique
Once the MR is isolated, a 15-mm long vertical transcutaneous incision is made directly over the anterior lacrimal crest down to bone depth. The insertion of medial palpebral ligament (MPL) is exposed by blunt dissection. The two arms of a double armed 5-0 non-absorbable coated braided polyester suture is passed through the superior and inferior part of MPL insertion at the anterior lacrimal crest including periosteum. The suture ends are tied to each other. Then either an empty semicircular needle or an artery forceps is passed under the skin and subcutaneous tissue toward the conjunctival side and used as a guide to bring out the two needles of the suture onto the conjunctival side. The sutures are then tied at the insertion of the MR directly onto the sclera, at the same time as the assistant rotates the globe medially (Figure 4). A slight overcorrection is desirable, as the sutures tend to get loosened with time. A case series by Sharma et al., of 4 subjects with a mean of 90 pd exotropia, showed satisfactory outcomes of <10 pd exotropia at 6 months following this technique, combined with supra-maximal LR recession.

Y split and medial transposition of LR muscle
This was first suggested by Taylor and later modified by Kaufmann and Gokyigit and colleagues.

Technique
A 300° conjunctivallimbalperitomy is made. The LR muscle is split up to 15 mm toward the posterior septum. One or two full-thickness locking bites are placed at the edge of the muscle halves using non-absorbable 6-0 polyester sutures. The muscle halves are disinserted and the sutures on
the muscle halves are passed through the hole of the Gass hook. Then the upper half of the muscle is passed under the superior oblique tendon behind the insertion with the help of the Gass hook and the inferior half of the muscle is passed between the sclera and both the IR and inferior oblique muscles. The lower and upper halves of the LR muscle are reattached 1 mm posterior to the inferior and superior border of the MR insertion, respectively (Figure 5). The mean improvement in exotropia ranges from 73 PD to 8 PD postoperatively. The same procedure has also been described on adjustable sutures, with successful outcomes. Combining this technique with MR resection showed promising results, as compared to Y-splitting alone.

**Restrictive strabismus**

**VRT for Duane’s retraction syndrome**

VRT has been described for Duane’s retraction syndrome (DRS) also, with highly successful outcomes. In a study by Akar et al., 40 eyes with esotropic DRS underwent VRT. The deviation was reduced by a mean of 95%; Abnormal head posture was eliminated in 86%; Abduction improved by 42%, and a useful binocular single field of 67% was achieved at the end of 1 year.

**Surgery for scarred conjunctiva**

Restrictive strabismus due to fibrotic conjunctiva following periocular surgery such as pterygium removal, can cause debilitating diplopia despite being a small-angle strabismus.

**Amniotic membrane transplantation**

Amniotic membrane transplantation seems to help prevent recurrence of adhesions in patients with restrictive strabismus caused by conjunctival scarring, fat adherence syndrome or rectus muscle contracture.

**Conjunctival mini-flap surgery**

This was first introduced by Akura et al. The procedure can be done under topical anesthesia and involves dissection of conjunctival hyperplasia and adhesiolysis. A tongue shaped flap is then fashioned from the adjacent virgin conjunctiva, and it is rotated and sutured such that it fully covers the bare sclera.

**Minimally invasive strabismus surgery**

Propounded by Gobin, and later popularized by Mojon, this is a technique of minimal access, wherein the conjunctival incision sites are essentially key-hole, placed strategically adjacent to the muscles to be operated. This reduces the postoperative irritation, dellen formation and improvescosmesis on first postoperative day. This principle of access has been adapted and developed further to allow to perform all types of strabismus surgeries, namely, rectus muscle recessions, resections, plications, reoperations, retro equatorial myopexias, transpositions, oblique muscle recessions and plications, and adjustable sutures. The incisions are 1–2 mm radial parainserital cuts, and may range in number anywhere between 2 and 6, depending on the type of surgery (Figure 6). Another technique of transconjunctival muscle reinsertion has also been described by him, where the needle is passed...
through the conjunctiva, and the sutures retrieved from the subconjunctival space.46

Conclusion

Great strides are being made in the field of strabismus surgery in recent years, with iconic innovators changing the way we look at strabismus surgery. There have been paradigm shifts in the approach to complex strabismus, based on the solid foundation of reasoning and better understanding of disease pathophysiology. Novel techniques have been aimed at improving consistency and predictability in outcomes. As a strabismologist, these are exciting times indeed!

References