Step by Step®
Squint Surgery

Foreword
Burton J Kushner

With DVD-ROM
STEP BY STEP®
SQUINT SURGERY
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Foreword

Burton J Kushner
Dedicated to

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Where the mind is without fear and the head is held high;
Where knowledge is free;
Where the world has not been broken up into fragments
by narrow domestic walls;
Where words come out from the depth of truth;
Where tireless striving stretches its arms towards perfection;
Where the clear stream of reason has not lost its way
into the dreary desert of dead habit;
Where the mind is led forward by thee into ever widening thought and action,
Into that heaven of freedom, my father let my country awake.

Rabindranath Tagore
(Gitanjali)
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This book, Step by Step Squint Surgery, edited by Dr Prasad Walimbe is a real jewel. As the title suggests, it provides a step-by-step approach to the common and not so common problems one encounters in the surgical management of patients with strabismus. It is straightforward, practical, full of useful pearls, and easy-to-read. Nestled between the front and back covers, in orderly fashion, are chapters dealing with the preoperative, intraoperative, and postoperative challenges the strabismus surgeons face. I think it belongs in a readily accessible spot on the bookshelf of the strabismus specialists, ophthalmology residents, and every comprehensive ophthalmologist who has the opportunity to treat strabismus surgically. They will certainly want to consult it frequently. I congratulate the authors on this worthwhile publication.

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The history of medicine in ancient times goes back to remote antiquity—somewhere between 4000 and 900 BC. The period between the seventh and first century BC saw an immense change in thinking process across the ancient world: Greece, China, Mesopotamia and India. In each of these widely separated centers of civilization, there was evidence of an advance in speculative thought of medicine. Since then, the world has seen sea changes in the field of medicine with its new branches, superspecialties, drugs, techniques, surgeries, philosophies and research.

The history of modern squint surgery starts from the end of eighteenth century. The first surgical trials consisted of performing myotomies of medial rectus. By the end of nineteenth century, surgical treatment of exodeviations was established. During twentieth century, progress achieved in anesthesiology, quality of suture materials and other techniques; further refined the squint surgery. Over the past decade, there has been a rapid evolution and advances in all ophthalmic superspecialties including strabismology. Despite the easy availability of extensive resources online to the ophthalmologists, accessing this ocean of information can be time-consuming and often confusing. Given the complexity and quantity of clinical knowledge required to correctly identify and surgically treat ocular motility disorders, a quick and practical reference book with step-by-step explanation of various techniques of squint surgery represents an invaluable resource to the busy general ophthalmologists as well as postgraduate students.
There are very few quality books which teach us practically how to do the basic steps in strabismus surgery. I feel this book will fill that void.

The purpose of this book is to present basic principles and technique of squint surgery in a step-by-step and easy-to-understand manner.

The squint surgery is a combination of dexterity, knowledge, judgment and experience which is gleaned over many years of practice. In this book, the stalwarts in strabismology have privileged us with their experience, which is definitely carried over in the contents of this excellent guide.

Theoretical learning of squint surgery must always be supported by a positive practical training and this book aims to help in giving that guidance. This book is written in a clear, logical and structured format with many illustrations, diagrams, photographs and is also coupled with high quality surgical video footage.

This book is divided into four sections, viz. preoperative considerations, preferred surgical techniques, postoperative considerations and recent advances; in which highly regarded and expert strabismologists have presented their strategic thinking in this field and described the nuances of squint surgery in a simple yet very effective, step-by-step and lucid approach.

I have been privileged to have the opportunity of first-hand studying all the thoughtful chapters from distinguished faculties in strabismology and I envy myself for that. I have gone through several proofreadings, debated on scientific layout of manuscripts and finally receiving, an eagerly awaited scholarly gift—the final printed version of Step by Step Squint Surgery—the labor has been very satisfying!
Preface

I sincerely hope that this book befriends your bookshelf and serves as a ready reckoner for general ophthalmologists, orthoptists, optometrists, residents in ophthalmology and squint specialists alike.

I also hope, the coming decade ushers in symbiotic advances in all specialties of medicine including ophthalmology and especially strabismology, where ophthalmologists will work for unity, achieve fusion and create a third dimension in spite of two disparate views— not only for the eyes but for the society as a whole!

Any suggestions from readers regarding any matter they believe could improve our future editions are welcomed.

Prasad Walimbe

References

ACKNOWLEDGMENTS

This book is the result of tremendous efforts of all authors, who are doyens in the field of strabismology and who dedicated their precious time for this endeavor. I am greatly indebted to all of them.

The authors' royalty from the sale of this book goes to Poor Children Spectacle Fund, Department of Pediatric Ophthalmology and Strabismus, Aravind Eye Hospital, Madurai, Tamil Nadu, India.

I would like to acknowledge all respected authors: Dr P Vijayalakshmi, Dr Stephen P Kraft, Dr Kalpana Narendran, Dr Sumita Agarkar, Dr A Ravichandar, Dr Milind Kiledar, Dr Arun Samprathi, Dr Mihir Kothari and Dr Ramesh Murthy, who kindly consented not to take their author’s remuneration for this noble cause.

I specially thank Dr Stephen P Kraft, Dr P Vijayalakshmi and Dr Kalpana Narendran, who in spite of their busy schedules, submitted their chapters before deadline.

I am immensely grateful to my teacher Dr P Vijayalakshmi, who considered me worthy for this job.

I express my heartfelt gratitude to my teacher Dr Burton J Kushner, who always encourages and supports me in all my ventures in this field.

I gratefully acknowledge M/S Jaypee Brothers Medical Publishers (P) Ltd, New Delhi, India and especially Mr Ramesh (Mumbai Branch) for their cooperation in the entire project.

I also wish to thank my wife Dr Tejaswini, my children Atharva and Ramaa and my parents for their continuing support.
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SECTION 1
PREOPERATIVE CONSIDERATIONS
Chapter 1

ANESTHESIA FOR SQUINT SURGERY

A Ravichandar
Anesthesia for ophthalmic surgery can be said to have had its origin when Karl Koller, an Austrian Ophthalmologist used cocaine to deaden sensation in the cornea. The anesthetic drugs and techniques available in the early period of anesthesia were not very satisfactory from ophthalmologic viewpoint. Straining associated with postoperative nausea and vomiting and airway compromise were rampant complications of general anesthesia which sometimes were severe enough to undo the benefits of the well executed surgical procedure. However, modern anesthetic drugs and techniques have introduced an element of safety and are considerably free from complications that hinder postsurgical well-being.

Ophthalmic surgery has witnessed an explosive development in its scope with the introduction of laser and other modern electronic gadgets; the range of patients who are subjected to this type of surgery encompasses all age groups – from the very young to the very old. This has implications for the anesthetist who must be proficient in the knowledge of factors concerning ophthalmic surgery as well as the myriad medical conditions which affect the conduct of anesthesia as well as recovery and safety.

It is always difficult to decide the age at which local anesthesia can be preferred over general anesthesia. Atkinson suggested that all patients younger than 10 years undergo general anesthesia and patients older than 65 years receive local anesthesia because of their increased medical risk due to coexisting medical conditions. Von Noorden indicated that apprehensive or nervous patients and those undergoing re-do surgery, surgery on the inferior rectus muscle as a result of thyroid disease and surgery on the muscles of both eyes should have general anesthesia. However, no hard and fast rule can be laid down and the decision has to be made individually based on
the condition of each case. As a general rule, long procedures, extensive or destructive procedures like evisceration or enucleation should be done on general anesthesia. The safety and comfort of the patient are paramount and the anesthetist’s/surgeon’s personal preferences should not stand in the way of choosing an appropriate technique for the patient.

**PREOPERATIVE ANESTHETIC EVALUATION**

Every surgery, however trivial, should be preceded by an anesthetic evaluation in order to identify medical problems that may compromise the outcome and also anesthetic problems which may interfere with the conduct of anesthesia. Parents of the pediatric patients are generally very anxious since the vision and future of their offspring hang in a balance. The opportunity to interact with them is well spent in explaining the risks associated with the procedure and anesthesia, if there are any. It is always prudent to give a moderate and realistic picture rather than a rosy and vivid scenario to avoid disappointment later if unexpected developments occur.

Presence of clear respiratory system is mandatory for smooth induction and maintenance of anesthesia. In the case of children with running nose, purulent discharge, productive cough and fever, it is better to defer anesthesia. However, the child with running nose due to incessant crying in the unfamiliar hospital environment can be taken for anesthesia with due caution. If the patient gives the history of infectious diseases like Chickenpox it is better to take up the patient for surgery after 3 weeks.

Medications for asthma, seizure, and other comorbid conditions should be continued perioperatively unless advice to the contrary is given by the anesthetist.
Juvenile diabetes patients present special problems. Insulin therapy is the rule with blood sugar levels taken as control. It is important to avoid hypoglycemia as well as ketoacidosis. Prolonged fasting is to be avoided and generally these patients are taken early in the list.

Congenital anomalies could be multiple and very often strabismus and Down’s syndrome may coexist. Down’s syndrome is associated with increased incidence of C1-C2 instability. If detected, excessive extension of the neck should be avoided, fiberoptic laryngoscopes and laryngeal mask airway should be ready for intubation. Cerebral palsy children are prone to recurrent seizures and since they often have increased incidence of gastroesophageal reflux, longer preoperative starvation is recommended for these patients. Craniofacial anomalies and airway abnormalities may also be present and special gadgets may be necessary for airway management.

**Preoperative Laboratory Test**

Minimum investigations in normal healthy children include baseline hemoglobin and hematocrit values to rule out occult anemia. Urine is examined for sugar. All asthmatic patients should have a preoperative chest X-ray.

Further investigations may be required if coexisting disease is present. This may include a cardiological evaluation in children suffering from congenital heart disease. In juvenile diabetics, HbA1c level estimation gives a better idea of glycemic control than random blood sugar estimation. Preoperative blood sugar and urine for acetone are done on the day of surgery.
STARVATION AND PREMEDICATION

Preoperative starvation is mandatory for all patients undergoing surgery under general anesthesia. It is safe to give clear fluids up to 3 hours before induction, and this helps increase the child’s comfort. It is mandatory to withhold solids for 6 hours before surgery. The importance of preoperative starvation and the sequence of anesthesia are explained to the parents and an informed consent is taken from them before surgery.

Anesthesia often begins with the administration of a sedative/hypnotic/narcotic drugs as premedication. Children presenting for surgery are found to be crying and struggling when separated from parents. Premedication paves the way for smooth transfer of the child to the operating room and also ensures smooth induction.

Nowadays, with the shift towards day-care procedures, premedication for pediatric patients is often omitted.

A vagolytic component is generally added to the sedative which ensures reduction of salivary secretions and prevents intraoperative oculocardiac reflex.

Inj. atropine (0.01 mg/kg) or glycopyrrolate (0.005 mg/kg) with Inj. midazolam (0.05 mg/kg) is given 30 mt before surgery. Oral midazolam in the dose of 0.5 to 0.75 mg/kg in flavored and palatable liquid is a better alternative to injectable premedication in anxious patients. The intravenous anticholinergic given just before induction as an alternative to intramuscular injection, is equally effective in preventing oculocardiac reflex.

CHOICE OF ANESTHESIA

- General anesthesia
- Local anesthesia
Squint Surgery

General Anesthesia

Majority of the patients who undergo squint surgery are children, although occasionally adults also may present for cosmetic correction. The surgery is usually carried out with general anesthesia because of the age of the patient. Good anesthesia is achieved with soft globe devoid of vascular congestion. Normal intraocular pressure (IOP) ranges from 10 – 20 mm Hg. Most anesthetic agents will decrease this. Table 1.1 describes the effects of commonly used anesthetic agents on IOP.

Table 1.1: General anesthesia

<table>
<thead>
<tr>
<th>Anesthetic Agent</th>
<th>Effect on Intraocular Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propofol, Thiopentone</td>
<td>IOP reduced by 20-30% (3-7 mm Hg)</td>
</tr>
<tr>
<td>Halothane, Sevoflurane,</td>
<td>IOP reduced by 20-30% (3-7 mm Hg)</td>
</tr>
<tr>
<td>Isoflurane, Desflurane</td>
<td></td>
</tr>
<tr>
<td>Opioids</td>
<td>Minimal to no effect on IOP</td>
</tr>
<tr>
<td>Ketamine</td>
<td>Increase in IOP; marked effect when dose exceeds 5 mg/kg</td>
</tr>
<tr>
<td>Atropine</td>
<td>No effect on IOP</td>
</tr>
<tr>
<td>Nondepolarizing muscle relaxants</td>
<td>Minimal to no effect on IOP</td>
</tr>
<tr>
<td>Suxamethonium</td>
<td>Significant increase in IOP within 30 secs of administration (approximately 8 mm Hg), effect lasts for 5-7 minutes</td>
</tr>
</tbody>
</table>

The choice of induction technique is either inhalational or intravenous. Intravenous induction performed with fentanyl combined with propofol or thiopentone is common. The inhalational induction with sevoflurane is an alternative technique especially in younger children. The airway
is best managed by intubation with paralysis and controlled ventilation. Access to the airway will be restricted during the surgery so it is important to secure the tracheal tube firmly. A preformed RAE tubes or a reinforced flexible tracheal tubes are preferable. Nowadays the reinforced LMA (Laryngeal Mask Airway) are used for most of the eye procedures. The advantages are reduced coughing at the end of the surgery and controlled ventilation with the use of muscle relaxants.

The nondepolarizing agents such as vecuronium are normally preferred over suxamethonium for two reasons. Firstly, patients who have been given suxamethonium have a prolonged increase in the extraocular muscle tone, which interferes with the FDT (Foreced Duction Test). This effect of suxamethonium lasts roughly 15-20 minutes. Secondly, patients undergoing correction of strabismus may be at increased risk of developing malignant hyperthermia. Anesthesia is usually maintained with oxygen, N\textsubscript{2}O and Sevoflurane/Propofol. As with induction, the choice of maintenance technique rests largely on the preferences of the anesthetist. Where halothane is used there is an increased risk of dysrhythmias, particularly where eye preparations containing adrenaline are used, and in the presence of hypercapnia, isoflurane or sevoflurane may be preferable.

Propofol has advantages in reducing the risk of postoperative nausea and vomiting (PONV) since propofol has antiemetic effects. At the end of surgery, the nondepolarizing muscle relaxant effect is reversed with neostigmine and glycopyrrolate. The use of glycopyrrolate is associated with a more stable cardiovascular system, fewer arrhythmias and superior control of oropharyngeal secretions at the time of reversal.
**Squint Surgery**

*Anesthetic Challenges in Squint Surgery*

**Intraocular pressure:** Anesthetic maneuvers like laryngoscopy and intubation, straining and coughing during induction and bucking on the tube by inadequately paralyzed patient will have the effect of causing an increase in the intraocular pressure. Attenuation of this effect is essential to obtain a soft globe. This effect may be attenuated by a dose of lidocaine 1 mg/kg 3 minutes prior to intubation or extubation. Use of the LMA permits smoother induction and emergence from anesthesia and has much less effect on IOP.

Unobstructed ventilation and lowering the PaCO₂ by moderate hyperventilation during anesthesia and a slight head up tilt ensure reduction in intraocular pressure and prevent venous congestion of the globe.

Hypoxia and hypercapnia both increase IOP and should be scrupulously avoided.

**Oculocardiac reflex:** Initially, described in 1908 by Bernard Aschner and Giuseppe Dagnini, the oculocardiac reflex is elicited by the pressure on the globe and by traction on the conjunctiva, orbital structures and extraocular muscles, especially the medial rectus. It is a trigeminovagal reflex. It is characterized by sinus bradycardia, nodal rhythm, ectopic beats or sinus arrest. Afferent pathway is via the long and short ciliary nerves to the ciliary ganglion terminating in trigeminal sensory nucleus in the floor of the 4th ventricle. Efferent pathway is from the motor nucleus of vagus nerve via cardiac depressor nerve of 10th cranial nerve, which ends in myocardium. Pressure, torsion or pulling of extraocular muscle may elicit this reflex. Successive provocations decrease the reflex sensitivity.

Intraoperative management depends upon the severity of the reflex. The importance lies in its early recognition.
Anesthesia for Squint Surgery

On realizing this event the surgeon should relax the muscle hook immediately. The bradycardia resolves almost immediately after the stimulus has been removed. If it persists the patient should be given intravenous atropine (0.15 mg/kg). In cases where the response to this treatment is poor, a retrobulbar lignocaine is recommended to block the afferent loop. Sevoflurane is less likely to provoke the reflex than halothane; it is also less likely with deep anesthesia compared to light anesthesia. The incidence of significant bradycardia is doubled if the carbon dioxide level is high, so controlled ventilation should be preferred over spontaneous breathing.

Nausea and vomiting: PONV is most common after squint surgery. The incidence of PONV after strabismus surgery varies from 46 to 88%. Most children have some pain after eye surgery and should be given analgesics without an opioid as it induces emesis. Prophylactic antiemetic in the combination of Inj. ondansetron 0.15 mg/kg with Inj. dexamethasone 100 ug/kg may be given along with premedication.

Postoperative pain: Even though most of the eye procedures have mild to moderate pain, squint surgeries have moderate pain which require stronger intraoperative and postoperative analgesics. These include paracetamol, NSAID, intravenous fentanyl, and peribulbar or sub-Tenon’s block before emergence from the anesthesia.

Others: Extubation should be considered in the deeper plane to avoid coughing and bucking in pediatric patients. Malignant hyperthermia a rare complication is sometimes associated with strabismus patients; it is commonly triggered by inhalational agents such as halothane and succinylcholine.
Local Anesthesia

Local anesthesia has become popular because of the increased use of adjustable sutures and the shift to day care procedures. Lignocaine 2 to 4% and Bupivacaine 0.25 to 0.75% are the commonly used anesthetic agents. It is often mixed with Epinephrine, 1:100,000 (or) Hyaluronidase. The choice depends on the anticipated duration of surgery. Adverse reaction can happen when the drug is accidentally injected into intravascular compartment, dural spread through the optic nerve sheath and drug sensitivity. Methods aimed at reducing these complications include proper techniques with careful positioning of the needle, aspiration before every injection and the use of a test dose. Direct injection into muscle can cause muscle necrosis. The inferior oblique, inferior rectus and medial rectus are most frequently involved. This can occur in sub-Tenon’s injection where the local anesthetic pools around the muscle. The risk is reduced by the addition of hyaluronidase.

The choices of local anesthetic techniques are:
- Retrobulbar anesthesia
- Peribulbar anesthesia
- Sub-Tenon’s anesthesia
- Topical anesthesia

Retrobulbar Anesthesia

The technique involves instillation of anesthetic solution into the intraconal space. A 1.5 inch, 25 gauge needle is used. Blunt tipped needles such as the Atkinson’s needle are preferred as the risk of globe perforation is minimal. After skin preparation, the inferior orbital margin is palpated to identify the junction between the outer 1/3rd and inner 2/3rd. The patient is asked to gaze straight ahead. This keeps the optic nerve out of Harm’s way. It should be
noted that Bell’s phenomenon will bring the optic nerve and the globe directly in the path of the needle and therefore, it is important to explain the procedure to the patient. The skin is entered with the needle parallel to the orbital floor for approximately 1 cm (Fig. 1.1). It is then directed medially towards the orbital apex as it advances posteriorly. A resistance is felt as the muscle cone is entered, more so, if a blunt needle is used. This is a subtle feeling and needs considerable experience to identify. The

Fig. 1.1: Retrobulbar anesthesia
injection is now given slowly. Usually 2-4 ml of solution is used. The needle is then withdrawn slowly and pressure is given on the globe over closed lids.

This technique achieves deep orbital anesthesia and akinesia and blocks the potential oculocardiac reflex with a minimal amount of anesthetic agent. The block effect is achieved in approximately 5 minutes. However, adjustment of sutures cannot be done at the earliest as the return of full extraocular motility takes long time, and this technique has increased the incidence of associated morbidity.

**Peribulbar Anesthesia**

Here the anesthetic solution is injected in the extraconal space. A 0.5 inch, 26 gauge disposable needle is preferred. More volume of anesthetic is needed and this technique is considered less effective than retrobulbar anesthesia. The injections are given at two sites. The first injection is given in the inferotemporal quadrant at the junction of the lateral 1/3rd and the medial 2/3rds. The needle is inserted parallel to the infraorbital margin along its entire length and may be canted upwards once the equator of the globe is crossed. No attempt is made to enter the muscle cone however. Gentle sideways movement may be done to identify engagement of the globe if any. Approximately 4-5 ml of solution is injected. The second injection is given in the superonasal quadrant at the junction of the lateral 2/3rd and medial 1/3rds. Again gentle sideways movement may be done to identify any accidental perforation. Once the needle is withdrawn, gentle pressure is given over the closed lids. The complications associated with this technique are less; but the risk of globe perforation exists, however it is less than with retrobulbar anesthesia. The block effect takes little longer than retrobulbar anesthesia, approximately 10 minutes. Pupillary dilatation indicates that adequate
anesthesia has been achieved, as the drug has diffused to the ciliary ganglion.

**Sub-Tenon’s Anesthesia**

Sub-Tenon’s anesthetic technique is safe, when compared to the other anesthetic techniques for strabismus surgery performed under local anesthesia (Fig. 1.2). The optic nerve function is not altered, which helps rapid visual recovery for the patient and earlier adjustment of adjustable sutures. The operating eye is prepared and draped, topical Proparacaine 0.5% is applied on the conjunctiva. The conjunctival and Tenon’s incisions are made; these incisions can be the same for the intended
strabismus surgery. Local anesthetic is injected into the sub-Tenon’s space through an irrigation syringe. The onset of block is as fast as retrobulbar anesthesia, and the block is usually performed in the course of surgery.

**Topical Anesthesia**

Strabismus surgery may be performed in select adult patients under topical anesthesia alone. Success depends on the experience of the surgeon and careful patient counseling and selection. This technique offers considerable advantage to the surgeon as single stage adjustment can be done right after the conclusion of the surgery. In addition, this technique obviates all the complications described associated with local anesthesia.

Various drugs including 4% lignocaine, amethocaine, and proparacaine have been used. Lignocaine Jelly 2% has been reported to give superior analgesia. The lignocaine jelly is applied to fill the fornices at least 20 minutes prior to the procedure. The application is repeated prior to the commencement. The patient is asked to gaze away from the muscle being operated to gain maximum view. It is important to avoid excessive traction on the muscle throughout the procedure as this can cause severe pain. The services of an experienced assistant will be invaluable at this juncture. It is better to avoid operating on the obliques and the superior rectus with topical anesthesia. It is also better to use complete regional/general anesthesia for resurgeries and complicated strabismus procedures. The surgery otherwise proceeds as it normally would. Should the patient report pain at any point? the surgeon should not hesitate to supplement with topical proparacaine/sub-Tenon’s lignocaine. It is important to remember that excessive supplementation can cause
corneal toxicity and alter the contractility of the muscle which may require the adjustment procedure to be delayed. The jelly is washed with saline at the end of the procedure. Supplementation of oral analgesics to the patients at the conclusion of the surgery is often helpful.

It is possible to augment topical anesthesia with the aid of sub-Tenon’s instillation of anesthetic solution or with intravenous sedation. In monitored sedation, patient is given Inj. Fentanyl 1microgram/kg with the continuous infusion of Inj. Propofol at the dose of 6 to 8 mg/kg/hr through the infusion pump. The patient is monitored with pulse oxymeter and blood pressure.

Monitored sedation is not a substitute for good patient counseling/selection. It is also not intended to replace general/topical anesthesia and only serves to make the surgeon’s job a little easier. The speedy recovery afforded by the newer sedatives, facilitate early adjustment. The patient should be made to understand that he/she will be given mild sedation and that his/her cooperation is crucial to the success of the procedure.

CONCLUSION

Eye is a delicate and sensitive organ. Consequently, any ophthalmic intervention including anesthesia has to be very refined and skilfully administered. Faulty maneuvers during anesthesia may negate the benefits expected from surgery. Careful attention to IOP and vascularity is essential; smooth extubation without coughing or straining is of paramount importance. Complete elimination/considerable attenuation of PONV is strongly indicated and the anesthetic technique and drugs administered should facilitate the achievement of this ideal. Adequate pain relief with drugs which do not induce PONV is indicated.
In short, ophthalmic anesthesia should not only enable eventless surgery but also should aid and facilitate quick functional recovery postoperatively.

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Chapter 2

STRABISMUS
ANATOMICAL PEARLS

Sumita Agarkar
A clear understanding of the anatomy including the extraocular muscles, periorcular fascia and orbit is a prerequisite to successful strabismus surgery. The conjunctiva, anterior and posterior Tenon’s capsule and muscle sheath play an important part in movement of the globe. These structures perform a passive role in initiation of movement but they play an active role in restriction of ocular movements.

The anatomical pearls are described under the following headlines:
- Palpebral fissure
- Conjunctiva
- Tenon’s capsule
- Muscles
- Sclera

**PALPEBRAL FISSURE**

The dimensions of palpebral fissure increase nearly 50% in width (from 18 mm in newborn to 28 in adult) and 20% in height (from 8 to 10 mm) between infancy and adulthood. Importance of fissure size lies in choosing the right sized speculum for adequate exposure during surgery. Further, the shape of palpebral fissure (mongoloid, antimongoloid) causes the appearance of patterns in squints (A or V pattern) and it should be considered during surgical planning.

**CONJUNCTIVA**

The bulbar conjunctiva loosely covers the anterior part of the globe from the fornices above and below and from the canthi medially and laterally. It becomes fused with the anterior Tenon’s capsule and sclera at the limbus.
Conjunctiva is thick in infancy and childhood and becomes thin and more friable in adulthood. This friability of conjunctiva precludes the use of fornicial incision in elderly.

Important surgical landmarks are:

a : Plica semilunaris
b : Caruncle
c : Fusion with underlying structures
d : Fat pad

Care should be taken to keep the position of plica and caruncle undisturbed while incising and repairing conjunctiva. Plica should not be placed laterally making it more obvious as an unsightly mass in the palpebral fissure.

Anterior to inferior fornix a fat pad is present that extends to within 12-14 mm of limbus. It is situated beneath the conjunctiva and its posterior condensations and is outside both the layers of Tenon’s capsule. A transconjunctival incision made medially or laterally should be made posterior to the line of attachment of posterior Tenon’s capsule or at least 8 mm from the limbus but anterior to inferior fat pad or no more than 12 mm from the limbus.

During extraocular muscle surgery incisions should be limited to the bulbar conjunctiva and should not extend to the fornical or palpebral conjunctiva as this causes unnecessary bleeding and serves no purpose. The parks’ cul-de-sac incision or fornix incision of extraocular muscles is actually made in the bulbar conjunctiva.

When a prior surgery has left the conjunctiva reddened and unsightly scarred which limits its mobility, the conjunctiva should be recessed with or without removal of tissue. If the sclera is left uncovered it becomes quickly covered with epithelium with out the need for any grafts.
TENON’S CAPSULE (FIGS 2.1 AND 2.2)

**Fig. 2.1:** Tenon’s capsule. (1) Limbal fusion of conjunctiva and anterior Tenon’s capsule, (2) Potential space between anterior Tenon’s capsule and sclera, (3) Muscle in its sheath (posterior Tenon’s capsule), (4) Postinsertional muscle footplates. (*Courtesy: Atlas of Strabismus Surgery by Eugene Helveston*)

**Fig. 2.2:** Coronal section of Fig. 2.1 at X: (1) Conjunctiva, (2) Anterior Tenon’s capsule, (3) Muscle sheath, (4) Extraocular muscle, (5) Intermuscular membrane, (6) Sclera. (*Courtesy: Atlas of Strabismus Surgery by Eugene Helveston*)
Strabismus: Anatomical Pearls

It is a thick structure with definite body and substance in childhood and becomes fibrillar and friable in old age. It is divided into anterior and posterior parts. Anterior Tenon’s is considered to be the vestigial capsulopalpebral head of rectus muscles. It overlies the anterior half of rectus muscles, intermuscular spaces and fuses with conjunctiva at the limbus.

Posterior Tenon’s capsule is composed of fibrous sheath of rectus muscles together with intramuscular septum. The Tenon’s capsule gets reflected on to the extra capsular portion of EOM for up to 12 mm backwards forming the muscular sheath. The muscle sheaths of the 4 recti muscles are connected by fibrous membrane known as intermuscular membrane, closely relating to each other. The blending of sheaths of IR and IO and its extensions on either side to sheaths of MR and LR form a suspending hammock ‘suspensory ligament of lockwood’ supporting the eyeball.

Fibrous attachments between the inner surface of anterior Tenon’s capsule and the outer muscle sheath are called check ligaments. Other attachments between outer surface of anterior Tenon’s capsule and the orbital rim medially and laterally are also called check ligaments.

Clinical Importance

- The connective tissue bands between recti and adjacent oblique muscle helps in locating the lost or slipped muscle. The absence of such fascial connections around medial rectus makes its retrieval extremely difficult if lost or slipped. Further a lost muscle slips into its sleeve once detached, so locating the muscle sleeve/sheath forms first step to locate the muscle.
Squint Surgery

- The clearing of anterior Tenon’s capsule off the tendon insertion is needed in order to prevent the slipped muscle. The surgeon may inadvertently secure the anterior Tenon’s capsule with sutures instead of the tendon fibres if it is not cleared off, thus allowing unsecured muscle to slip posteriorly.

- Posterior Tenon’s capsule barrier keeps orbital fat separated from the globe and EOM. The violation of this barrier results in fat prolapse through torn Tenon’s capsule and scars to the sclera or EOM, i.e. fat adherence syndrome. This can be prevented by carefully dissecting close to muscle belly or sclera and thus not disturbing posterior Tenon’s integrity (Fig. 2.3).

Fig. 2.3: Insertion of posterior Tenon’s capsule at the level of rectus muscle insertions. (Courtesy: Atlas of Strabismus Surgery by Eugene Helveston)
The check ligaments connect superior and inferior recti to the levator muscle and lower lid retractors respectively. A recession or resection of vertical rectus muscles requires removal of these ligaments in order to avoid lid fissure changes after surgery.

**MUSCLES (FIGS 2.4 AND 2.5)**

![Diagram of eye muscles](image)

*Fig. 2.4: Actions of extraocular muscles—right eye. (Courtesy: Surgical Techniques in Ophthalmology-Strabismus Surgery, Jaypee-Highlights)*
Horizontal Rectus Muscles

Medial Rectus

Originates from the annulus of Zinn at the orbital apex and inserts 5.5 mm from the limbus. Just above the muscle lies the ophthalmic artery, the superior ophthalmic vein and the nasociliary nerve.

Its sole action in primary position is adduction.

Surgical Points

The vertical action can be brought into play during surgery by transposing the muscle insertion up or down to produce elevating or depressing effect respectively.

Fig. 2.5: Location and width of extraocular muscle insertions in mm
Medial rectus has no fascial attachments to other muscles and can therefore retract to apex of the orbit once severed from the globe.

The insertion of MR varies from 3-6 mm and this variability of insertion makes it a poor landmark for measurement during recession. Thus, the use of limbus as the point of reference for recession of MR as suggested by Helveston et al.

Medial rectus is a tight muscle and has limited contact with the globe. This shorter arc of contact makes it ideal to be weakened by faden procedure. The terminal tendinous portion is only 4 mm long. Resections >4 mm cause more bleeding and if greater than 6 mm it will result in limited abduction, narrowing of the palpebral fissure and retraction of the globe. Similarly, recessions more than 6 mm will cause limited adduction.

**Lateral Rectus**

This muscle lies adjacent to lateral orbital wall and runs at an angle of 56° from the medial rectus and visual axis. The insertion is 6.9 mm from the limbus and the primary action is abduction. Just above the muscle lies lacrimal artery and nerve.

**Surgical Points**

Recession >7 mm can limit abduction whereas resections can limit adduction if greater than 8 mm.

Attachments between the lower border of lateral rectus and inferior oblique should be freed during resection to prevent damage to inferior oblique or anterior dragging of muscle.
Vertical Rectus Muscles

The vertical recti run in line with the orbital axis and are inserted in front of the equator. They form an angle of 23° with the visual axis.

Superior Rectus

Originates from the upper part of the annulus of zinn and inserts 7.7 mm from the equator. The primary action is elevation and the secondary actions are adduction and intorsion.

Surgical Points

Recessions more than 5 mm limit upgaze. In recessing the muscle, there are fascial attachments between the muscle and superior oblique, which must be divided before the procedure to be effective. Resections of 5 mm or more can limit downgaze.

Embryonically the superior rectus stems from the same mesoderm as the levator muscle which lies above and runs parallel to the superior rectus. Its fascial connections to levator are to be dissected to avoid lid fissure changes as said earlier.

Inferior Rectus

Originates at the inferior part of Annulus of Zinn and inserts 6.5 mm behind inferior limbus.

The primary action is depression and secondary actions being adduction and extorsion.
Strabismus: Anatomical Pearls

Surgical Points

The capsule is connected to inferior oblique, the lid structures through check ligaments and through attachments to lockwood’s ligament all of which must be freed during recession to limit lower lid retraction.

Recessions greater than 5 mm can limit downgaze. Resections greater than 5 mm can draw up the lid narrowing the palpebral fissure.

Spiral of Tilaux

The imaginary line joining the insertions of four recti. It is an important anatomical landmark when performing surgery.

Oblique Muscles

Inferior Oblique

Originates at the medial end of inferior orbital rim at the outer crest of lacrimal fossa, proceeds temporally and posteriorly at an angle of 50° beneath inferior rectus (Fig. 2.6).

Inserts beneath inferior border of lateral rectus 12 mm from the insertion of inferior rectus. The posterior extent of insertion lies 2 mm below and lateral to macula.

Surgical Points

The inferior vortex vein leaves the sclera 8 mm posterior to the inferior rectus insertion along its temporal border loops just posterior to the inferior oblique and must be avoided.

Blood vessels that supply inferior oblique will not contribute to the blood supply of anterior segment.
Fig. 2.6: Inferior oblique muscle

It receives innervations on its upper surface at the point where it passes beneath inferior rectus lateral border. Since innervated in middle it may be weakened either proximal or distal to its point of innervations. Injury to the nerve during surgery can cause internal ophthalmoplegia as it contains parasympathetic fibres that supply intrinsic ocular muscles.

Weakening procedure done lateral to lateral border of inferior rectus causes the new functional insertion of inferior oblique to be at its point of union with lockwood's ligament beneath inferior rectus.
Superior Oblique

The superior oblique muscle has a muscular part and a tendinous part both of which are 30 mm long. Originates at annulus of Zinn, becomes tendinous 10 mm posterior to trochlea, then it passes posteriorly and temporally beneath superior rectus to insert near lateral border of superior rectus. The average anterior point of insertion is 13 mm from the imbus. The SO tendon between trochlea and medial border of superior rectus is 3 mm in diameter and covered by dense fascia which may cause difficulty in identifying it (Fig. 2.7).

The insertion of superior oblique is variable. Insertion near medial border of superior rectus, absence of superior
oblique tendon also reported. Helveston has classified the anatomical variations of SO into four types.

Whitnall’s ligament (superior transverse ligament) and superior oblique tendon have common fascial attachments near the trochlea. If it is weakened inadvertently while hooking superior oblique tendon, can lead to ptosis of nasal portion of upper lid. So, it is safer to hook the same under direct vision and preferably at its insertion.

The site of superotemporal vortex vein is 8 mm behind the equator and close to the insertion of superior oblique and it must be avoided during surgery.

**Blood Supply**

Anterior ciliary arteries travel in the four rectus muscles. Each of the rectus muscle has got two anterior ciliary arteries with the exception of the lateral rectus which has one. As a general rule not more than two rectus muscles should be detached at one operation as it can lead to segmental iris atrophy in older individuals (Fig. 2.8).

The four vortex veins are located behind the equator a few millimetres on each side of the superior rectus and inferior rectus muscles. Every effort must be made to avoid severing a vortex vein. If a vortex vein is cut pressure should be applied to prevent bleeding. Cautery should be avoided.

**SCLERA (FIG. 2.9)**

The thickness of the sclera varies depending on the site
- at the limbus—0.8 mm
- anterior to rectus muscle insertion—0.6 mm
- posterior to rectus muscle insertion—0.3 mm
- at equator—0.5 mm
- at posterior pole—1 mm thick.
**Fig. 2.8:** Anterior ciliary blood vessels. Cross-section relationship of vessels to sclera (S), muscle and intermuscular septum (M), Tenon's fascia (T) and conjunctiva (C). *(Courtesy: Complications in Ophthalmic Surgery)*

**Fig. 2.9:** Thickness of sclera at different sites. *(Courtesy: Eugene Helveston)*
The goals of a strabismus evaluation are:
- To establish a cause for strabismus, i.e. whether infantile esotropia, restrictive or paralytic causes.
- To assess binocular sensory status.
- To measure the deviation.
- To diagnose amblyopia.

Thus, an evaluation which is done with these goals in mind will prevent lengthy examination which often results in an uncooperative patient and a confused clinician. It is equally true that despite a focused evaluation, patient’s strabismus may refuse to fall in a specific category.

The order for examination of a patient with strabismus is:
- History
- Visual acuity
- Sensory tests
- Measurement of deviation
- Ductions and versions
- Special tests
- Cycloplegic refraction
- Fundus examination

HISTORY

A detailed history is a must before you start examining the patient. History taking should be based on patient’s chief complaints like squinting, diplopia or asthenopia. Duration of squinting, age of onset of squint, any apparent precipitating factors like trauma or febrile episodes or cerebrovascular accident should be asked for.

Past history should include history of patching, spectacle wear, any history of trauma, any history of previous surgery for strabismus, cataract, retinal detachment, blow
out fracture, glaucoma implant or any periocular surgery like sinus surgery or neurosurgery.

Birth history should include – age of gestation, birth weight and any significant events in antenatal and postnatal period. There should be a mention of developmental milestones if it is normal or delayed.

Family history is extremely important in cases of certain hereditary forms of strabismus and response of other family members to surgery will give a clue to patient’s response to surgery.

Leading questions should be asked about associated neurological signs and symptoms like seizures, ataxia, muscle weakness, fatigue, ptosis, etc.

**VISUAL ACUITY (VA)**

This is one of the most important parts of the examination. It can often be a test of patience for the examiner if the patient happens to be a child. Visually a newborn has a VA of 6/240 which increases to 6/90 by 1st month. By age of 4-6 months VA varies between 6/18-6/6 and by 3 years it should be 6/6. Behavior of child can often give a clue to visual acuity especially in extremely young children. By the age of one month most infants turn eyes and head at light source and can track light source horizontally. **Preverbal children**: In preverbal children visual acuity can be assessed in following ways:

**Fixation Pattern**

Fixation should be central, steady and maintained. Unsteady or wandering or eccentric fixation usually indicates poor visual acuity. In a patient with strabismus, fixation preference
for a particular eye also indicates poor visual acuity in the other eye.

Fixation preference can also be tested by using a vertical prism. In this test, we place a vertical prism of 15PD base up or base down in front of one eye, which induces a vertical strabismus and look for refixational movement. For example, if we place the prism base down in front of the right eye and there is a refixational movement in upward direction, then it indicates right eye is fixing but it also indicates that left eye is not fixing. This test is useful to detect amblyopia in straight eyes, or those in whom angle of strabismus is small.

**Optokinetic Nystagmus (OKN)**

It can be used to assess visual acuity in very young children. Highest spatial frequency which produces a response can be quantified to give visual acuity. It has limitations in the sense, that target must be presented in a rigidly standardized condition which is difficult in clinical settings. Moreover, OKN response has a sensory and a motor component so an infant with a normal sensory system may still have abnormal OKN, if a motor problem exists. Another fallacy of the test is that OKN response may be normal in cases of cortical blindness.

**Teller Acuity Cards (Fig. 3.1)**

It is a behavioral test in which subject is offered a choice between black and white grating and plain area of same size and equal luminance. It is based on principal that child will prefer to look at grating than plain area. Visual acuity can be quantified by spatial frequency of grating presented.
Response of child is observed by observer through a peep hole. Spatial frequency of grating presented gives an estimate of visual acuity. This test usually overestimates visual acuity.

**Visually Evoked Potential**

It can also be used to get an idea of visual acuity, though it tends to be a little unreliable in a child below one year. SWEEP-VEP may be useful in such patients.

**Preschool children:** There are a number of matching tests in which child is asked to match the letter or symbol by a replica or a matching card. These include Sheridian Gardiner, HOTV, Tumbling E test, Allen cards, STYCAR Lea symbols, etc (Figs 3.2 to 3.6). All these tests should be first demonstrated at near distance so that, child is able to comprehend the test.
Fig. 3.2: Recognition acuity—Allen cards

Fig. 3.3: Preferential looking tests—Lea’s paddles
**Fig. 3.4:** Recognition acuity—Lea’s symbols

**Fig 3.5:** Recognition acuity—‘E’ chart
Older children: VA can be tested using Snellen's chart or near vision test.

Visual acuity in nystagmus: It is difficult to assess monocular vision in a patient with nystagmus. Because occluder placed over one eye often worsens the nystagmus and causes decline of VA so while recording VA, we have to provide some peripheral binocular clues to prevent worsening of nystagmus, at the same time permit monocular assessment of vision. It can be done by remote occlusion, i.e. occluder is placed at some distance in front of one eye or we can use high plus lenses to check the other eye. Neutral density filters can also be used. Binocular VA should also be recorded because that is often better than monocular VA.
SENSORY TESTS

It is an integral part of strabismus evaluation. It is done with patient wearing full refractive correction. It includes:
1. Tests for stereopsis
2. Tests for retinal correspondence
3. Tests for suppression.

Tests for Stereopsis

Tests for stereopsis usually incorporate two essential features: They dissociate eyes, i.e. each eye is presented with a separate field of view and each of the two views must contain elements imaged on corresponding retinal areas. Stereopsis must be noted for near as well as for distance. Distance stereoacuity often gives a better indication of control of intermittent squints.

**Near stereoacuity (Fig. 3.7):** It is assessed by following methods:
- Titmus stereo test
- Randot stereograms/TNO
- Lang’s test
- Frisby test

![Fig. 3.7: Sensory tests—stereoacuity](image)
Squint Surgery

**Titmus stereo test:** There are vectograph cards which dissociate eyes optically. Patient needs to wear polaroid glasses to appreciate stereo images. It is simple and can be used in clinical setting. Only disadvantage is that this test has monocular clues, it tends to overestimate stereopsis.

**Randot stereograms:** These stereograms are devoid of monocular clues. Patient needs to use polaroid glass. TNO test is also based on random dot but patient needs to wear red green glasses to get stereoscopic effect.

**Lang’s test:** It is useful in children who refuse to wear red, green or polaroid spectacles. It is based on pantographic presentation of random dot pattern. Eyes are dissociated through the cylindrical elements imprinted on surface lamination of card.

**Frisby test:** It can be used for assess stereopsis for near. It also does not require special spectacle.

**Distance stereocuity:** It can be measured by American Optical Vectograph which uses polarized glasses. Mentor B Vat system is new addition to assess stereopsis for distance. It is a computerized system in which liquid crystal binocular glasses are provided which are connected to a microprocessor. Each eye is presented with disparate images at a high frequency. So that stereopsis is achieved.

### Tests for Retinal Correspondence

Retinal correspondence is ability of sensory system to appreciate the perceived direction of fovea in each eye, relative to the other eye. The two eyes have corresponding retinal elements that have a common visual direction. For example, both foveas share the straight ahead direction.

Normal retinal correspondence (NRC) is seen in straight eyes or when subjective and objective angles of deviation
are same. In anomalous retinal correspondence (ARC), fovea of deviating eye loses common visual direction with the fovea of fixing eye, and fovea of fixing eye shares a common visual direction with a peripheral retinal element of the deviating eye. Anomalous retinal correspondence can be harmonious or unharmonious. Retinal correspondence can be assessed by using:

Bagolini’s striated glasses which have narrow striations oriented at 45° and 135°. These glasses allow evaluation of retinal correspondence in physiological conditions (Fig. 3.8).

After image test can also be used to evaluate ARC. In this test, each fovea is stimulated separately. Vertical after-image is presented to deviating eye because suppression scotomas are along horizontal meridian while horizontal after image is presented to the fixing eye. In NRC, a cross is seen with a central gap. In esotropia with ARC, after images are crossed but in exotropia with ARC—after images are uncrossed.

Fig. 3.8: Bagolini’s glasses
Major amblyoscope can also be used to assess retinal correspondence. If subjective and objective angle of deviation are same, it indicates NRC (Fig. 3.9).

Worth 4 dot test can also be used to assess anomalous retinal correspondence. If patient reports four lights in presence of manifest deviation, it indicates anomalous retinal correspondence.

Tests for Suppression

Suppression is alteration of visual sensation resulting from inhibition of one eye’s images from reaching consciousness. It is a sensory adaptation to avoid diplopia. It is a purely binocular phenomenon. Suppression can be central or peripheral, monocular or alternating, facultative or obligatory.

Fig. 3.9: Major amblyoscope—Synoptophore
MEASUREMENT OF DEVIATION

Worth 4 Dot Test (Fig. 3.10)

It should be done for near and distance. Patient wears red-green goggles and views 4 lights, 1 red, 1 white and 2 green. Red is traditionally worn over right eye. If patient reports only 2 red or 3 green lights, left or right eye suppression is respectively present. 5 lights indicate diplopia. 4 lights indicate fusion or ARC. It is a useful test though it tends to dissociate the eyes and poor quality of red-green glasses permits monocular clues. A new polarized version of 4 dot test is now available.

Fig. 3.10: Worth 4 dot test
4 Prism Diopter Baseout Test

This test demonstrates small foveal suppression scotomas associated with microtropias. In a person with bifoveal fixation if a 4 prism diopter base-out prism is placed in front of right eye, right eye will move nasally and left eye temporally followed by a refixational movement in left eye (i.e. eye without prism). If a suppression scotoma exists in right eye, the placing of prism will not elicit any movement in either eye. While, if we place the prism in front of left eye, right eye will show initial conjugate saccade towards apex of prism but there will be no refixational movements.

Bagolini’s glasses can also detect suppression. Patient will perceive only 1 line.

Motor Testing

Head Posture (Fig. 3.11)

Comitant heterotropias usually have a normal head posture. Abnormal head posture is seen in incomitant squints, A/V patterns, nystagmus or in some strabismic
entities like Duane’s or Brown’s syndrome. Anomalous head posture is adopted either to avoid diplopia or achieve binocularity. Abnormal head posture can take form of face turns or head tilts. There can be a chin elevation or depression. However, nonocular causes of anomalous head posture like hearing loss, psychogenic, torticollis should also be kept in mind.

**Position of Lids**

Position of lids and palpebral fissure should also be examined. Any ptosis or pseudoptosis should be differentiated and recorded.

**Binocular Motor Functions**

There are four types of ocular alignment tests.

- Corneal light reflex tests
- Cover tests
- Dissimilar image tests
- Dissimilar target tests.

**Corneal Light Reflex Tests**

These tests are useful to assess ocular alignment in patients with poor cooperation and those patients who have poor fixation.

**Hirschberg’s Test (Fig. 3.12)**

This test is based on premise that 1 mm shift in light reflex from the center is equal to 7° of deviation of visual axis. Therefore, a light reflex at pupillary margin which is 2 mm away from center corresponds to 15° deviation. In mid iris region it is equal to 30° and at limbus it corresponds to 45° deviation.
Modified Krimsky’s Test (Fig. 3.13)
This test utilizes light reflex from both eyes. The patient fixates a pen light with his better eye and prisms are added till light reflex is centered in the deviated eye. This roughly gives the amount of deviation. The observer should be seated directly in front to avoid parallax.

Bruckner test: In this test, a direct ophthalmoscope is used to elicit a red reflex from both eyes simultaneously. Reflex from deviating eye is usually brighter.

Cover Tests (Fig. 3.14)
Cover test remains gold standard for assessing and measuring deviation. Basic requisites for cover tests are eye movement, capability for image formation and perception, foveal fixation and cooperation of the patient. Cover test has three components—cover test, cover/uncover test and alternate cover test.

In cover test, we cover the apparently fixing eye and note the movement of other eye. If other eye moves to take up fixation it indicates the presence of manifest squint. If there is no movement in fellow eye then that eye is
Strabismus Evaluation

Covered and other eye is observed. Cover test is performed for both near and distance fixation. Cover test not only establishes the presence of a manifest strabismus but it also helps to diagnose latent nystagmus which becomes obvious when one eye is covered. It also gives an idea of degree of alternation of strabismus. In a true alternator when fixing eye is covered, other eye takes up fixation and maintains fixation at least through a blink, when cover is removed. Cover test also indicates the presence of eccentric fixation if any. The eye with eccentric fixation continues to fix in from a deviate position if the fellow eye

Fig. 3.13: Modified Krimsky’s test
Squint Surgery

is covered. In small children, cover test can be facilitated by putting occluder at a distance or using a translucent Spielman occluder. A pen light should never be used as fixation target as it has a poor control of accommodation.

Cover/uncover test is a test to detect latent strabismus. In this test as one and then other eye is covered while patient fixates at a target, movement of the eye under the cover is noted as the cover is removed. If eye moves in to take fixation, it indicates exophoria and if it moves out, it indicates esophoria.

In alternate cover test, the total deviation is measured. It does not differentiate between latent and manifest strabismus. It can be combined with prisms to measure the angle of deviation (Prism Bar Cover test). To perform this test we alternately cover each eye while patient maintains fixation. Prisms of increasing strength are placed in one
Strabismus Evaluation

eye with apex oriented towards direction of squint (i.e. base in for exotropia) till no redressal movement is elicited. This is also called as simultaneous prism and cover test. If vertical and horizontal squint exist together then first horizontal and then vertical angle is measured.

The amount of prism required to offset all redressal movements is the angle of deviation. This test is also done for both near and distance. Small accommodative fixation targets should be used for near and 6/9 vision acuity line for distance fixation. Pen light should never be used.

It is necessary to dissociate eyes before measuring the angle so cover should be placed alternately few times and patient should not be allowed to regain fusion and compensatory mechanisms to check the deviation. If patient has a refractive error, the angle should be measured both with and without glasses for near and distance. It is important to remember that high plus lenses decrease and minus lenses increase the measured deviation. Prisms used for this test can be loose prisms or prism bar. Glass prism should be held in Prentice position and plastic prisms in frontal plane position. Wrong positioning can give right to wrong measurements. While measuring large angles it is preferable to divide prism in both eyes. Stacking of prisms often produces errors, specially, if a low power prism is added to a high powered one.

Dissimilar Image Tests

These are tests based on diplopia principal. The diplopia is produced by presenting two dissimilar images. Diplopia can be spontaneous as in case of paralytic squint or has to be elicited, if there is suppression or ARC as in case of comitant squint. In these tests we determine subjective localization of a single object imaged on fovea of one eye
and extrafoveal point in other eye. Distance of double image can be crossed as in exotropia or uncrossed as in esotropia. The different tests are:

- Red filter test
- Maddox rod
- Double Maddox rod test.

**Red Filter Test**

In red glass test, a red filter is placed over fixating eye to differentiate two visual fields. Patient fixates over a small light and reports whether red image is crossed or uncrossed, up or down. Red glass should be dark enough to dissociate as well as differentiate the eyes. Sometimes, a vertical prism may be added to the red filter to appreciate diplopia better.

Maddox rod is a lens which consists of a series of parallel cylinders which convert a point source of light to a streak which is oriented perpendicular to that in Maddox rod. Maddox rod also dissociates the eyes. One eye perceives a point of light while the other sees a red vertical line, if Maddox rod is placed horizontally. If the line bisects the light there is orthophoria, if it is on right side of white light, there is esodeviation and if it is on left side an exodeviation is present. This test cannot differentiate between heterophoria and tropia. Maddox rod is also traditionally worn over right eye.

It can be used to detect horizontal as well as vertical deviations. To measure vertical deviation, cylinders are placed vertically, to measure the angle, prisms are placed with apex in direction of deviation till line crosses the light. Maddox rod can also be used to measure torsion. It is placed in vertical direction. Patient is allowed to rotate the lens till one becomes horizontally straight. Degree of torsion can be read off the trial frame.
**Double Maddox Rod Test (Fig. 3.15)**

This is used for diagnosing cyclodeviations. A red Maddox rod is placed in front of right eye while a white one is placed in front of left eye with cylinders aligned vertically so patient sees two horizontal lines. Patient is allowed to rotate axis of rod till two lines are aligned and parallel. Deviation can be read in degrees directly from the trial frame.

*Fig. 3.15: Double Maddox rod test*
**Dissimilar Target Tests**

They are based on haploscopic principle, i.e. patient’s response to dissimilar images created by each eye viewing a different target. These tests are invaluable for incomitant squints. The only prerequisite for this test is the presence of NRC. The deviation is measured with first one eye fixation and then other. The common tests done are:

**Hess’ Screening (Fig. 3.16)**

This test utilizes red-green goggles and a screen that has a red light in 8 inner and 16 outer positions and a green slit projection. Patient sits at 50 cm and is asked to put green slit over each of red dot. Goggles are then reversed to record secondary deviation. A polarized version of Hess’ screen is also available.

![Hess’ screening](image)
Strabismus Evaluation

Lancaster red/green test: This test also has a screen with squares. Patient wears red green goggles and sits at 2 meters. Examiner projects red slit on screen while patient tries to coincide with green slit in his hand. Goggles are then reversed to record secondary deviation.

Major amblyoscope: It projects dissimilar target which patient is asked to superimpose. The deviation can be read directly off the scale.

DUCTIONS/VERSIONS (FIG. 3.17)

There are three types of ocular movements. Ductions are monocular pursuit movements. Versions are binocular pursuit movements while vergences are binocular movements where eyes move in opposite directions. To check for ocular motility, patient fixates at a small fixation target and it is moved in the diagnostic positions of gaze, i.e. up right, right, down right, up, down, up left, left, down left and primary position. Ductions are first tested and then versions. Any overaction or underaction of muscle are noted, any A or V pattern should also be noted. To measure motility- Kastenbaum’s limbus test of motility can be used. This test is done by holding a transparent ruler in front of eye and if you want to measure abduction, position of nasal limbus is marked on ruler in primary position and on maximum abduction, the difference is noted in mm. Similar way adduction, elevation and depression can be noted. Normal values for abduction, adduction and depression are 10 mm and for elevation it is 5-7 mm. Clinically speaking, in normal adduction an imaginary vertical line through lower lacrimal punctum should coincide with inner 1/3 and outer 2/3 of cornea. If more cornea is hidden, there is excessive adduction and if sclera remains visible it is
defective. In normal abduction, corneal limbus should touch outer canthus, if limbus passes that point abduction is excessive and vice-versa.

Fusional vergences amplitudes should be noted using synoptophore or prisms.

It is useful to measure near point of convergence and AC/A ratio in selected cases of strabismus.

**SPECIAL TESTS**

**Forced Duction Test (Figs 3.18 and 3.19)**

This is done to differentiate between restrictive and paralytic strabismus. Indications for forced duction test are incomitant squints, thyroid ophthalmopathy, blowout fracture, Duane’s and Brown’s syndrome. To perform this test, topical anesthetic drops are applied. Eye is passively moved with forceps in direction of limitation of movement. Passive movement is possible in neurogenic pathology while it is not possible in restrictive pathology.
Forced Generation Test (Fig. 3.20)

It is done in paralytic squint. In this, patient is asked to move the eye in a given direction while examiner fixes the eye.

Saccadic Velocity

This is also a useful test to differentiate between neurogenic and restrictive pathology, it provides a graphic record of speed and direction of eye movements. It needs special apparatus.

Field of Binocular Vision

This is done on Goldman perimeter or on tangent screen. It tests the limit of version movement. Normal field of binocular fixation measures around 45-50° from fixation point.
It is absolutely essential to get refraction under cycloplegia for a case of strabismus. Atropine, which is the strongest cycloplegic, is preferred in very young children. It is contraindicated in infants and patients with Down’s syndrome.

Adverse reactions to atropine like allergic reaction, flushing, dryness and fever should be explained to parents.

In older children, we can use shorter acting cycloplegics like cyclopentolate and Homatropine. It is advisable not to use tropicamide which has very weak cycloplegic action.

Fig. 3.20: Forced generation test

**CYCLOPLEGIC REFRACTION (FIG. 3.21)**
**Strabismus Evaluation**

**FUNDUS EXAMINATION (FIG. 3.22)**

*Fig. 3.21*: Cycloplegic refraction

*Fig. 3.22*: Fundus examination for torsion

- **Normal fundus**
- **Incyclotorsion**
- **Excyclotorsion**
Fundus examination is last but not the least part of evaluation of strabismus. Many cases of sensory esotropia and exotropia are associated with disorders of optic nerve and retina.

Similarly, fundus examination can also give information about oblique overaction which produces shift of foveal reflex which is visible on indirect ophthalmoscopy.

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COUNSELING FOR SQUINT SURGERY

Milind Killedar
It was not very uncommon to have squint patients going untouched or unattended to, in a general ophthalmic practice. However, with an increased awareness and availability of more trained pediatric ophthalmologists and strabismologists, more and more squint patients are attended to. Squint is such a social taboo that at the time of marriage it is considered to be a handicap. While if one gets it in the next generation the same mother or father who avoided a squinting partner now become reluctant to have an early consultation or treatment for the child. Even if made aware of the squint many people are not keen to get something done for it. On the other hand, a fine DVD or very minimal residual squint after a surgery may still keep the patient unhappy. So counseling for squint is difficult task to convince a patient at the same time make him aware of the uncertain outcome of the procedure. Because we all know that in surgery we are offering a mechanical solution to a nonmechanical problem. In the best of hands an orthotropia (deviation less than 10 prisms) is achieved in approximately 85% of cases. So, still in 15% of cases one has to face under or overcorrection. So explaining this uncertainty is the main motto of counseling from surgeon's point of view.

**PREOPERATIVE COUNSELING**

- Explaining the type of squint he has
- Conveying the decision to operate
- Developing counseling materials/models.

**Explaining the Type of Squint**

It is always best to acquire a digital photograph of patient in our own electronic medical record. Comparing it with
standard photos of esotropia, exotropia, hyper or hypotropias becomes easy for the patient to understand the same. Having a 9 cardinal gaze photograph of some standard conditions like Duane’s syndrome, Brown’s syndrome is useful in explaining difficulties in treating such conditions. Moreover, the uncommon conditions like superior oblique procedures or transpositions of muscles may be difficult to explain to the patient without an actual eye model (Figs 4.1 to 4.4).

**Fig. 4.1:** Esotropia

**Fig. 4.2:** Exotropia

**Fig. 4.3:** Hypertropia
Conveying Decision to Operate

Next important part is to convey the patient which eye needs to be operated and how many muscles to be operated. It is better to explain him that it is a balance of total 12 muscles of two eyes that make a perfect balance. At this juncture, it is easy to explain the charges per muscle which is easy to understand. This also makes it easy to explain the additional need of operating extramuscle in case of under or overcorrection. Also to explain him if we are planning surgery in two parts (right eye first and then left eye after a gap of 2 months). This gives opportunity to measure smaller angles more accurately than larger angles. If an adjustable surgery is planned it is better to explain the next day procedure first hand, otherwise it could be taken as unwarranted additional procedure. Usually, this much knowledge is sufficient for the patient to understand the need for surgery.

As regards the surgical technique if it is fornix based incision, it is useful to give emphasis to it as suture less surgery as some surgeons do it. Moreover, the postoperative
comfort of the patient is excellent and the ability to get back to normal work is also quick (usually within a week’s time) as against the limbal incisions. Although, use of tissue adhesives like Reliseal to close the conjunctiva can bring the same comfort in limbal incision surgery also.

**Developing Counseling Models**

Have handy information brochures, powerpoint presentations or actual eye models on counseling table (Figs 4.5A and B). This helps a lot. The most effect is seen by comparative pre- and postoperative pictures of patients operated at your own clinic being displayed.
POSTOPERATIVE COUNSELING

It is very important to explain the next day appearance of the eye as edematous lids, red conjunctiva sometimes bloody tears for a day or two. All of this can be very horrifying for an uninformed patient. Also an uninformed diplopia is very irritating. However, if it is well explained prior, it will be tolerated well. Also one should explain that it is going to disappear soon. However, in an untoward incidence of persistent diplopia prism therapy or resurgery should be done.

Facing an Unexpected Situation

Sometimes, in spite of the best efforts of explaining, patient may misunderstand the eye to be operated or in reality we
Counseling for Squint Surgery

may operate wrong eye (according to patient). We know as far as it is comitant squint results will not vary and there is no need to panic. However, as soon as it is brought to our notice, patients’ relatives should be calmly counseled that the change in eye was purposeful and taken after careful examination under anesthesia (e.g. FDT). Although, it might not be truth. However, if it was incomitant squint or wrong surgery, i.e. recess instead of resect or vice versa then it is better to explain the facts and plan a redo immediately.

Most of the book mentioned complications in squint surgery like malignant hyperthermia, panophthalmitis are so rare that one may not see a single case in the lifetime. So such, things need not be touched in routine pre- or postoperative counseling as it may cause unnecessary worries. However, if it occurs, it can be explained as very rarely occurred complication and should be energetically managed. The competency of a surgeon is not only to do a surgery greately but also to manage complications efficiently.

Lastly, it is a very good practice to get a follow-up photograph of patient at one month and show him the comparison between the preoperative and postoperative photograph.
SECTION 2
PREFERRED SURGICAL TECHNIQUES
Chapter 5

INSTRUMENTS FOR STRABISMUS SURGERY

Arun Samprathi
Strabismology surgery is one of the cheapest subspecialties in ophthalmology, whether it is in the outpatient or the operation theater. Minimal instruments are necessary for strabismus surgery, which relies more on technique and surgeon’s expertise than on instrumentation. A basic cataract set available in any OT is sufficient to perform a horizontal muscle surgery. Though, there are advances in surgical techniques in strabismus surgery, the instrumentation has not changed much in the last few decades.

We can classify the instruments as mandatory instruments and optional instruments.

**MANDATORY INSTRUMENTS**

**Muscle Hooks**

Muscle hooks are the most important part of a strabismus instrument set. Standard muscle hooks have smooth, rounded tip, which do not damage the muscle when passing under it. These hooks are useful for initial hooking of the muscle (Fig. 5.1).

![Muscle hooks](image)
**Calipers (Castroviejo Caliper)**

Calipers are very crucial for measuring the exact distance for recession or resection of a muscle. A standard caliper available in the cataract set is most commonly used (Fig. 5.2).

**Westcott’s Scissors**

The curved and blunt tips allow easy dissection of the Tenon’s capsule from the sclera with little risk of perforating the scleral wall (Fig. 5.3).

**Needle Holder**

Good pair of needle holders is essential for performing a safe strabismus surgery. Taking bites at correct depth is important to avoid scleral perforation (Fig. 5.4).

![Fig. 5.2: Castroviejo caliper](image-url)
Suture Tying Forceps

Suture tying forceps are essential for securing the sutures firmly on the muscle as well as the sclera (Fig. 5.5).

Fixation Forceps

Good stabilization of the globe is necessary, particularly while taking scleral bytes and while doing fornix based strabismus surgery (Fig. 5.6).
Fig. 5.5: Suture tying forceps

Fig. 5.6: Fixation forceps

**OPTIONAL INSTRUMENTS**

**Modified Muscle Hooks**

Jameson muscle hooks have a small projection at the tip to hold the muscle for passing the sutures and tying them.
Chavasse hooks have an undulated horizontal surface, so that it allows for passing the central suture and then tying them at either edges of the muscle (Figs 5.7A and B).

**Barbie Retractors**

Surgery on the extraocular muscles needs good exposure, particularly in children with narrow palpebral apertures, re-surgeries, restrictive strabismus, etc. Barbie retractors are of great value to get a good exposure, without damaging the tissues. Barbie retractors could be small, medium or large depending on the needs (Fig. 5.8).

**Bull Dog Clamps**

Bull dog clamps are useful to hold the sutures separately. So that they do not get mixed-up while tying.

**Muscle Clamps**

Resections of muscles can be done with the help of muscle clamps to hold the muscle. Muscle clamps will prevent the muscle from slipping and retracting back into the orbit (lost muscle), which is a serious complication (Fig. 5.9).

**Scleral Rulers**

Special scleral rulers are available, which have the same curve as the sclera. These rulers are useful when measuring recessions from the limbus or for posterior fixation sutures.
Figs 5.7A and B: (A) Jameson muscle hooks (B) Chavassee hook

Fig. 5.8: Barbie retractor

Fig. 5.9: Muscle clamps
Curved Locking Fixation Forceps

These forceps are useful for stabilizing the globe after disinserting the muscle, so that scleral bytes can be taken in the correct direction, without rotating the globe.

MISCELLANEOUS INSTRUMENTS

- **Speculum**: A solid blade or wire speculum which can give a wide exposure is desirable (Fig. 5.10).
- Mosquito clamps
- BP handle.

LIGHT SOURCE

Operating microscopes available in all modern ophthalmic operating rooms are sufficient for most strabismus surgeries. Though some surgeons prefer to use loops, I would recommend the use of operating microscope for beginners as it gives a very good illumination as well as good depth perception for proper scleral bytes. Loops have the
advantage of allowing free movement of the surgeon particularly while operating on the obliques or operating deep inside the orbits.

**PULSE OXIMETER**

Monitoring the pulse constantly throughout the procedure is extremely essential. Bradycardia due to oculo-cardiac reflex is a dreaded complication of strabismus surgery and needs immediate recognition and prompt management. Hence, strabismus surgery should never be attempted without a pulse oximeter and an anesthetist to monitor the patient.

**CONCLUSION**

Strabismus surgery can be performed with minimal instrumentation available in all ophthalmic operating rooms (Fig. 5.11).

*Fig. 5.11: Instruments for strabismus surgery*
INTRODUCTION

Strabismus surgery aims to improve the alignment of the eyes to achieve or preserve binocular single vision apart from providing a good cosmetic result. Sometimes it is aimed at correcting the head posture thereby increasing the binocular field of vision. It is mandatory that all patients are examined in detail, refractive errors are corrected adequately and amblyopia, if any was treated with full enthusiasm before planning for surgical correction of strabismus. We try to give a few guidelines on decision making and surgical principles in this chapter.

IMPORTANCE OF GOOD PREOPERATIVE EVALUATION

A very careful and detailed preoperative workup is mandatory to the successful outcome of strabismus surgery. Readers are advised to read the concerned chapters for the details on this. Few points of clinical importance are stressed here.

Sometimes the presenting complaint may be an abnormal head posture, which could be so simple as preference to fix with one eye (amblyopia), or complicated like a congenital superior oblique palsy, congenital elevation deficiency, restrictive strabismus like Duane’s, Brown’s or fibrosis syndromes, nystagmus and nystagmus blockade syndrome. All efforts should be done to diagnose the etiology of head posture including estimation of binocularity and the treatment is directed towards improving it. The next important point is to know under and overactions of both recti and oblique muscles which will actually indicate the muscles to be operated. For example, in cases of pattern deviations and in DVD associated with oblique muscle overactions, that should be
Principles of Strabismus Surgery

weakened unless indicated otherwise. The most difficult in this part is estimating the amount of deviation which will tell us how many muscles to be operated. The choice of surgical procedure depends upon the relationship of near and distance deviation, lateral incomitance, pattern deviations and presence of amblyopia, stressing again the importance of detailed measurements in all required positions of gaze by using a prism cover test with a correct target to fixate. The surgery should be deferred until the surgeon is convinced that he has at least two high quality measurements not differing more than 5 to 10 prism diopters each especially in all patients.

The binocular single vision with corrective prisms and stereopsis if possible should be estimated in every case, to predict the possible postoperative outcome. Delayed milestones if it is present should be given its due importance. The other associated findings like age of the patient, fissure changes, other rarely associated syndromes should also be recognized.

AGE OF THE PATIENT AT SURGERY

Patients less than two years of age tend to have smaller globes and the surgery tends to give more effect for each millimeter of muscle recessed/resected. The general consensus is that the strabismus surgery should not be done in children less than 4 months of age. Few authors claim better sensory outcome when it is performed 3 to 4 months of age. They also agree that the deviation must be constant and reproducible with repeated examinations before undertaking the surgery (Rosenbaum Book). Various clinical trials have proved that there are better chances to gain binocularity, fusion with bifoveal fixation, if it is performed below the age of 2 years. One
study reports that 41% of infants whose eyes were aligned within 8 prism diopters in the first 16 months of life had the restoration of random dot stereopsis years later, that whose eyes were aligned at the age of 12 months atleast 49% achieved stereopsis of finer grade. Still some amount of peripheral fusion may be possible even when the surgery is done in later years especially in acquired deviations. It is wise to delay the surgery in cases with global developmental delay, in situations where the measurement of the deviation is not satisfactory, variable deviations, dense amblyopes and reluctant parents.

**BILATERAL SYMMETRICAL SURGERY**

Surgery should aim to restore symmetry and alignment to the maximum possible extent. Some authors believe that this can be achieved only by symmetrical surgeries and they advocate this unless otherwise indicated. However, a bilateral medial rectus recession is commonly done for infantile esotropia with cross fixation, near deviation more than distance, (convergence excess type) V pattern with no oblique dysfunction and in accommodative esodeviation. Bilateral lateral rectus recessions would be of value in divergence excess exotropia, intermittent exodeviations, V pattern deviations. These bilateral recessions can be combined with shifting of muscles up or down or with bilateral inferior oblique weakening depending upon the pattern deviations. Bilateral resections are rarely done, e.g. a bimedial resection may be useful in exotropias of pure convergence weakness and bilateral lateral rectus resections in large A pattern esotropias with no inferior oblique dysfunction.
Unilateral Recess/Resect (R/R) Procedure

Recessions/resections result in a greater effect in the direction of the action of the muscle and this can be used to the surgeon's advantage. R and R on the same eye tends to correct the same amount of deviation both for distance and near. Hence, this procedure is indicated when the patient was already treated for amblyopia, definite dominance of one eye, parents feel the deviation present in only one eye, when the deviation is secondary to the pathology in the eye (sensory strabismus). In cases of very large deviations, where more than 2 muscles surgery is indicated. Recess resect in one eye will be a better option for making the decision on the residual deviation rather than doing a symmetrical procedure two times.

SINGLE MUSCLE SURGERY

Single muscle recession has a more value in small deviations and is more useful in vertical muscle surgery. In horizontal deviations, especially in esotropias a single medial rectus recession may be indicated when the deviation is less than 20 prism diopters. This could be either a primary deviation, with or without an accommodative component, or residual deviations after a first operation in the fellow eye or in Duane retraction syndrome with a small face turn. However, a caution should be kept in mind that large recession of a single muscle may give rise to incomitance in the field of action of the muscle, sometimes resulting in double vision in that field. So a careful assessment of the postoperative effects on side gaze measurements are necessary preoperatively and it is better to limit the number maximum to 6 mm recession. Single lateral rectus recession is rarely indicated except in small intermittent exophoria
or a tropia. Inferior rectus recession especially in small vertical deviations may be useful and a superior rectus recession can be done in unilateral DVD.\textsuperscript{11}

Single muscle resection again has a limited role and may be indicated in small residue, a pattern with no oblique dysfunction. Resection of a single muscle has lesser disadvantages than a recession as far as incomitant results are concerned.

**MUSCLE SURGERY**

When the deviation is large and the intention is a maximum correction in one sitting a recess resect in one eye can be combined with other eye recession especially in exotropias. Overcorrections are known and caution is advised.\textsuperscript{12}

**Influence of Muscle Surgery on Palpebral Fissure**

It is important to remember that medial rectus recessions result in a widening of the palpebral fissure and resections narrow it. Careful consideration is needed for a good outcome. Inferior oblique anteropositioning can also narrow the palpebral fissure and also result in a bulge in the lower lid. inferior rectus recession may produce a lower lid lag.\textsuperscript{13} The patient should be warned of these potential side effects.

**Amount of Correction**

The main aim is to correct the maximum deviation in one sitting, and distribute the surgery to 2 muscles whenever indicated. Getting the numbers right is not that simple. The average values are 4.5 pd per mm for the medial rectus and 3 pd per mm for the lateral rectus. The limits for recession
are 6 mm for the medial rectus and 8 mm for the lateral rectus.\textsuperscript{14} Minimal recession for lateral rectus is 4 mm and for the medial rectus is 3 mm. According to Pratt-Johnson\textsuperscript{15} the effect of surgery, recession or resections on previously unoperated horizontal muscle is 2.5 prism diopter correction per mm and this increases with the amount of surgery done. At 7 mm one tends to get 3 prisms diopter and at 10 mm it is 5 mm. This gives the predicted effect in about 85\% of his patients meaning that reoperation may still be necessary in 15\% of the patients.

In cases of inferior rectus recession one mm recession corrects 3 prism diopters in primary position whereas that will be 5 prism diopters in downgaze. This should be carefully considered in preoperative decision making. Pratt-Johnson also reports that a large recess resect can be done occasionally in large unilateral deviations and he observed that the initial weak ductions get better over time as the muscle gets readjusted and also admits that this is unpredictable. Surgery on a tight muscle primarily and resurgeries like advancements and resections will have more effect than expected. For that reason an adjustable suture technique may be used in this situation.

There are many tables published\textsuperscript{14,16} and one can follow them initially for a few cases till he or she reviews his own patients and formulates the surgical dosage.

\textbf{Effect of Axial Length and Refractive Error on Muscle Surgery}

Response to Strabismus surgery does correlate significantly and inversely with axial length. This correlation may not be clinically very important, given the much stronger influence of preoperative deviation.\textsuperscript{17}
For a better outcome each case should be individualized and the final decision should be made depending upon the age of the patient, amount of deviation, presence of amblyopia, presence of refractive errors and finally the patient’s expectations. A checklist prior to taking the patient for surgery may be helpful for the beginner.

- Vision, refraction and cycloplegic refraction
- Has appropriate optical correction been given?
- Has amblyopia treatment been completed?
- Likely compliance with postoperative patching, glasses and follow-up
- Measurement in relevant directions of gaze, measurement for distance and near with and without glasses
- Was the patient cooperative for the measurements? Are you satisfied or would you rather delay the surgery until accurate measurements are obtained?
- Tests for binocularity and stereopsis
- Prognosis for achievement of binocular single vision after surgery
- Ocular movements carefully recorded with attention to over and underactions
- Is the surgical plan adequate to tackle incomitance, A and V patterns and oblique overactions?
- Comprehensive anterior and posterior segment evaluation
- Attention to systemic risk factors especially towards administration of general anesthesia
- Attention to other factors like patient cooperation for local/topical anesthesia
- Patient consent form duly signed with clarification of doubts
- Preoperative checks to ensure the right eye and the right patient is being operated upon.
ANESTHESIA

We routinely use general anesthesia for all patients less than 18 years of age. For older patients, local (retrobulbar/peribulbar) or topical anesthesia (Lignocaine jelly and proparacaine drops with or without systemic augmentation with Fentanyl and Propofol) is used with heart rate being monitored throughout the surgery. The technique to be used depends on the consensus between the patient, surgeon and the anesthetist. Topical anesthesia may be avoided for oblique muscles. The eyes may straighten out under general anesthesia and it is important that the surgeon should not change his/her decision based on this.

SUTURES AND NEEDLES

6-0 vicryl sutures are preferred for the routine recess resect procedures on the muscles. Non absorbable sutures like Prolene 5-0 and merseilene are used in Muscle transpositions, muscle surgery after RD surgery with buckle, resurgeries, and globe fixation procedures. 8-0 vicryl is used to close the conjunctiva. Always spatulated needles are recommended for muscle surgery.

ON THE TABLE

The conjunctival sac is cleaned with povidone iodine along with the lids and brows. The eye to be operated is confirmed before draping. Forced duction test is performed on all eyes as a first step, since a tight muscle will give rise to better correction on its recession when compared to a normal muscle and an adjustable suture can be placed in such situations where the results are unpredictable.
SPECIAL CONSIDERATIONS FOR PARETIC STRABISMUS

The surgeon must remember that in cases of paretic deviations, if he is operating on the paretic eye he must correct for the primary deviation, but if he is operating on the normal eye, the secondary deviation must be taken into account.

Weakening either the antagonist or the yoke muscle to the paretic muscle is physiologically sound and should result in the best improvement when all fields of gaze is taken unto consideration. Which muscle to be chosen depends upon the predictability of results. For example in an inferior rectus paresis, it is easy to operate on the direct antagonist superior rectus with precision than operating on the other eye superior oblique (yoke muscle) with less precision. Strengthening the paralysed muscle depends whether the paralyzed muscle is able to exert any force (as can be determined by analysis of saccadic velocity, the globe crossing the midline and the forced generation test). If yes, a routine recess/resect procedure will do. Any restriction caused by contracture of the antagonist (tested by the forced duction test) has to be relieved. If no active force is generated, recessing the antagonist muscle may be of limited value as the muscle in the absence of opposing force eventually takes up the slack and the strabismus recurs. Similarly, resecting a completely paralyzed muscle is of little value as the muscle in the absence of any active contraction eventually stretches out. A transposition procedure as described in later chapters is of value in these conditions. This generates a constant force. When attempting to look in the field of the paralyzed muscle, the antagonist relaxes and the constant force pulls the globe to some distance, thereby expanding the binocular field of single vision. Third nerve palsy leaves us with little
options as most of the muscles are affected. If the globe is able to cross the midline, a recess/resect procedure on the horizontal recti improves alignment. If not, the lateral rectus may need to be inactivated by suturing it to the orbital periosteum and the medial rectus resected. Another option is to perform a large recession of the lateral rectus and anchor the globe to the medial palpebral ligament or the periosteum of the medial orbital wall. It is important to remember that alignment can be achieved only in the primary position. In cases of spread of comitance the recess resect procedure can be chosen. The use of adjustable sutures play a great role in treating such patients.

In cases of 6th nerve palsy, the decision of surgical procedure again depends upon the ability of the globe to abduct. The same principles hold good here also. Either the recession of medial rectus alone or in combination with resection of the lateral rectus if that is functioning. If not a Jensen’s procedure is the choice. For 4th nerve palsy refer the chapter on vertical strabismus.

PREVENTING COMPLICATIONS

Strabismus surgery is generally rated as a safe surgery with minimal or no complications that can be done by anyone with residency training in ophthalmology. I agree with the fact that strabismus surgical techniques per se is not that difficult to learn and one can avoid surgical complications. Keeping in mind that this a very sensitive cosmetic surgery apart from its sensory outcome, with high expectations from patient’s side and considering that resurgeries are difficult and unpredictable, a proper decision making is mandatory and that needs definitely an experience which has its own learning curve.
Careful preoperative evaluation, selection of the appropriate procedure and judicious use of adjustable techniques as detailed in the preceding sections and in the chapters to come goes a long way in minimizing overcorrections and undercorrections. To ensure patient satisfaction, the parents/patient should be involved in the decision making process regarding the eye to be operated, choice of anesthesia, etc. Even though the procedure is extraocular, postoperative infection is still a possible entity. Hence, it is important that aseptic precautions of the same degree as for any other ocular surgery be employed. Meticulous surgical technique reduces the chance of muscle slippage and globe perforation. Traction on the extraocular muscles should be kept to a minimum for two reasons. One it avoids the oculocardiac reflex and two aggressive traction in the elderly can lead to the muscle snapping called the pulled in two syndrome (PITS). For resurgeries, if there is an option to operate on the virgin muscle, that should be preferred rather than on the muscles previously operated on. Anterior segment ischemia can be any surgeon’s nightmare. It is discussed in detail in a later chapter. The use of a fornix incision, limiting the number of extraocular muscles operated on a single eye (the obliques do not matter, but under no circumstance should all the four recti be detached from the globe even in staged procedures), vessel sparing procedures, attention to systemic atherosclerotic risk factors, avoidance of surgery on two adjacent recti tend to minimize this dreaded complication.

For essentially one eyed patients (e.g. other eye with severe amblyopia, macular pathology, etc.), perform the maximum possible surgery in the affected eye, and usually do not advocate surgery on the good eye unless otherwise indicated.
Last but not the least, the systemic condition of the patient should receive due attention. The surgeon should work in close coordination with the anesthetist to ensure safe surgery.

**POSTOPERATIVE CARE AND FOLLOW-UP**

At conclusion of surgery, a drop of antibiotic steroid combination is instilled in the conjunctival sac and the eye bandaged. The bandage is removed the following day and we recommend rest for 14 days. If both eyes have been operated, the bandage on one eye is removed an hour after surgery and that on the other eye removed the next day. The patient is discharged on a steroid antibiotic combination with instruction to use it for a month (low potency steroids like fluorometholone or loteprednol are preferred. For fornix incision a shorter course for a week or two is sufficient). On the first postoperative day, the eyes are examined mainly for the alignment, congestion, conjuntival opposition and for any gross pathology.

Review is timed, a month after the surgery. Careful examination is done to note any sutural allergic reactions, healing of the wound in general, the alignment of the eyes, estimation of visual acuity, binocular vision, fusion and stereopsis, fundus examination with refraction when indicated. Any small refractive correction is given especially if there is a residual deviation. Amblyopia therapy if needed can be resumed as early as two weeks after the surgery. Further follow-ups are planned 6 months thereafter upto 8 years when the results said to be getting stabilized. Special follow-ups are given for whom the amblyopia treatment is advocated, or prisms are prescribed.
To conclude, an adequate knowledge on the vision development and amblyopia forms the basis for an ophthalmologist to become a strabismus surgeon, and to achieve this, the teaching and training should be incorporated into our postgraduate training in an adequate amount and this learning should be continued further in practice. A lot of reading, strict adherence to surgical principles, careful planning, interaction with peers and colleagues, using telemedicine will increase the individual’s confidence over time and will contribute in the making of a successful strabismus surgeon.

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HORIZONTAL MUSCLE SURGERY FOR STRABISMUS

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INTRODUCTION

Surgery on the horizontal recti is the simplest of squint surgeries and the novice surgeon usually commences his training by beginning with them. There are numerous variations in the technique, but the basic principles remain the same. We try to give some practical pearls in learning these techniques and have made a sincere attempt to keep the contents as simple as possible.

MAGNIFICATION

Magnification is recommended either in the form of loupes or microscopes. As almost all surgeons in India practice cataract surgery under microscope, using the microscope for strabismus procedures will make it more practical. We routinely use the surgical microscope for all our surgeries.

PREPARATORY STEPS

The eye or the eyes are cleaned with povidone iodine after confirming the eye to be operated. Some surgeons prefer to use phenylephrine hydrochloride on the table to induce vascular constriction which we are not practicing. Forcedduction testing is done to identify any restrictive component. A traction suture can be used to pull the globe and expose the area of incision.

CONJUNCTIVAL INCISION

The Swan incision, where the incision is made at the insertion of the muscle is not practiced widely. The surgeon has the choice of either the limbal or the fornix incision. The fornix-based incision needs a more precise surgical
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Technique and needs a good assistance throughout the surgery. The limbal incision is our preferred choice and will be dealt in detail. The limbal incision gives the best exposure of the two with almost a less learning curve and is recommended for beginners. Some rotation of the globe occurs during general anesthesia and the surgeon should exert caution to avoid operating on the wrong muscle. It is usually possible to see the muscle through the conjunctiva with the speculum in place. Useful clues include the ciliary vessels and a darker appearance compared to the surrounding. This can be used to guide the placement of the incision.

After cleaning and draping, the surgeon grasps the conjunctiva at the limbus with a toothed forceps at an identified location (5 o’clock position) and a small incision is made with Wescott’s scissors. The conjunctiva along with Tenon’s is now separated from the sclera upto the muscle insertion by passing the closed scissors from below upwards before the incision is extended concentric to the limbus for two to three clock hours, e.g. starting from 5 o’clock position and ending at 2 o’clock position in case of surgery on medial rectus. Two radial incisions are made approximately for 5 mm starting from the ends of the concentric incisions. Precaution is to be taken to note any big vessel crossing the line of incision. If it is not possible to avoid cutting the vessel, one can use cautery either before or after cutting the vessel. Inappropriate location of the incision can result in muscle injury with bleeding or an ugly scar postoperatively.

**EXPOSURE OF THE MUSCLE**

The conjunctiva is then retracted back and the intermuscular septum is buttonholed by blunt dissection.
with Wescott’s scissors to expose bare sclera. Once the sclera is exposed, the muscle is engaged with a gentle sweep of a blunt tipped hook like the Von Graefe’s or Jameson’s. The movement should be smooth and any resistance in a previously unoperated muscle means that the surgeon is in the wrong plane of hooking or hooking only part of the muscle. Two hooks passed from either side can be used to ensure complete hooking. Two hooks placed one behind the other can also be used to give the surgeon room for passing sutures and disinsertion. Some surgeons use a hook with a groove (the Wright’s grooved hook) for tight muscles.

The intermuscular septum is now cut on either side. The check ligaments should be dissected carefully by a combination of blunt and sharp dissection. Care should be taken to preserve the muscle sheath as cutting the sheath results in bleeding and more postoperative adhesions. The cuts on the intermuscular septum and the check ligaments should be done under direct visualization with small snips. The incision on the check ligaments should be made close to the muscle, taking care not to cut the muscle, or cut the muscle fascia.

The next step is to pass another hook a little posterior to the first one and a gentle sweep is made with a hook between the muscle and the sclera to detach any posterior adhesions to a desired distance. Too much posterior sweep may result in bleeding. The retraction of the conjunctiva for better exposure of the muscle can be done either with the serrated edge forceps or a muscle hook, Desmarre’s retractor may be required very rarely. The conjunctiva should only be retracted and not pulled up as this will cause tenting up of the vessels. Care should be taken not to cut these. The distance to which dissection is carried out is usually 6 mm for the medial rectus and 8 mm for the lateral rectus (may be a little more for resections). For
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WEAKENING PROCEDURES

Recession

Recessions are the most commonly performed procedure, where the muscle is disinserted and attached some distance from the origin. Once the muscle is hooked and dissection completed, 6-0 vicryl sutures are placed on the muscle (one at each end) before disinsertion as shown in the figure. The surgeon may place the sutures either in front of or behind the hook. In any case, the sutures should not be placed more than 1mm from the insertion. A bite is taken from inside out. Locking bites are used. A 2–1–1 square knot is tied on the muscle at the end of the surgery. Two single armed sutures or one double armed suture, placed on either end of the muscle. Before cutting the muscle the direction of the muscle posteriorly is marked on the sclera, if there is no landmark visible (ciliary vessel invariably). It can be marked on any one end with the methylene blue stain which is commonly used by us and the muscle is cut with a Wescott scissors from its insertion. As an alternative one can use a mild cautery mark. While cutting the muscle, the surgeon should make deliberate short snips taking care not to cut the suture or sclera. The point indicating the recession distance is then marked on the sclera from either end of the insertion and should be perpendicular to the insertion. Particular care is needed in fornix incisions because of the distorted anatomy. The Vernier calipers are routinely used.
for measurement. We have found the Scott’s curved ruler to be very useful in a situation where large recessions are indicated. Experts differ on the reference point for measurement. Some surgeons routinely use the muscle insertion, while others use the limbus. For example the average distance of the medial rectus from the limbus is 5.5 mm. If at surgery, the medial rectus insertion is found 4 mm from the limbus, a recession of 5 mm measured from the insertion would place it 4 + 5 = 9 mm from the limbus. If the limbus is taken as the reference, the new distance from the limbus assuming an average insertion distance of 5.5 mm would place it 5.5 + 5 = 10.5 mm from the limbus. There is still controversy as to which approach is superior, but it is wise to remember that the former approach is prone to undercorrections, while the latter runs a greater risk of overcorrections. We prefer to measure from the insertion site unless otherwise indicated like in resurgeries.

Muscle reattachment requires a meticulous technique. The planned site of reattachment should be marked with dye or simply by indenting the calipers. While making the needle pass, the surgeon should be able to see the tip all along. If he/she cannot see the same, the possibility of perforation should be considered and ruled out by an indirect ophthalmoscopy on table. Care should be taken to ensure that the needle has passed through the sclera and not merely the episclera. A longer pass is more secure because of greater friction preventing slippage of the suture. Once bites have been taken, the sutures are tied with a 2–1–1 squared knot. Too tight a knot should be avoided as this can result in necrosis of the scleral bridge. If the surgeon is unsure of his scleral bite or is unable to make one because of a thin sclera encountered on table, or in cases of high myopes a hangback or a semi-hangback
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suture can be used for better safety. In cases of lateral rectus recessions of 8 to 9 mm, it is important to remember that the fovea is lying just there and precautions are taken to avoid perforation.

For hangback technique, the surgeon passes the two sutures through the center of the insertion and ties a knot after allowing a slack in the suture to account for the recession distance. In hemi-hangback technique, the suture is placed little anteriorly, for example, in cases where 8 mm of lateral rectus is planned, the suture is placed at 5 or 6 mm from the insertion and for the remaining 2 to 3 mm, the muscle is allowed to hang.

Conjunctival Closure

At conclusion of the surgery, the conjunctiva is reposited back and sutured with 8-0 vicryl. A good apposition is mandatory for good cosmesis. Bunching of the conjunctiva should be avoided as this can persist and present as a thick scar. Including the Tenon’s in the conjunctival suture can result in a permanent red discoloration as the Tenon’s has a salmon pink color. For surgeries on the medial rectus, the surgeon should be careful not to pull the plica/caruncle while suturing the conjunctiva. There is usually some discomfort caused by the sutures. This, however, is transient. The conjunctiva can be recessed in patients with scarring of the conjunctiva as is not uncommon in patients with trauma and in patients who have undergone retinal buckling. The need for this procedure is dictated by the forced duction test, which if relieved after the conjunctival incision, indicates a tight conjunctiva, and necessitates suturing the conjunctiva some distance away from the limbus.
Exposure of the Muscle with Fornix Incision

To expose the medial rectus a traction suture is placed adjacent to the limbus in the inferonasal quadrant. The globe is now pulled in the opposite direction and an incision made 8–10 mm away from the limbus with a Wescott’s scissors. The intermuscular septum is now cut to expose bare sclera. The muscle is hooked with a von Graefe hook, which is then exchanged for a Green’s hook. The Green’s hook is ideally suited for this purpose. The hook has a projection which prevents the muscle from falling out. The muscle is now prolapsed out of the incision with the aid of a Steven’s hook. The intermuscular septum is now button-holed to bare the tip of the Green’s hook and is moved into the button hole. Dissection of the intermuscular septum and the Check ligaments is as for the limbal incision. At conclusion of the surgery, the incision on the conjunctiva is opposed with a cotton bud or forceps. Inferior incisions can be left unsutured. Incisions placed in the superior quadrant usually require a suture or two to avoid prolapse of the Tenon’s tissue.

Other Weakening Procedures

Free tenotomies have been given up for the most part except for certain special situations like strabismus fixus convergens and on extremely tight muscles. Z tenotomies of the horizontal recti are rarely practiced these days. They have been reported to be useful in undercorrections following nystagmus surgery.

Faden Operation

The faden operation is done by suturing the muscle to the sclera with a non-absorbable suture at a specified distance
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(12–14 mm for the medial rectus, 14–16 mm for the vertical recti measured from the insertion). This weakens the muscle in the direction of action of the muscle but does not affect primary position deviation. Faden on the lateral rectus is not very effective because of a larger arc of contact and is usually reserved for the medial rectus. This is of value in some conditions like nonaccommodative esotropia with a high AC/A ratio where the patient may be orthophoric for distance, but shows a large esotropia for near. The amount of dissection of the check ligaments and the intermuscular septum is much more than for routine recessions and should be adequate to make an easy placement of the suture. A Desmarre’s/Barbie retractor is very useful for this purpose. This can be either combined with recession or done alone.

**Faden suture without recession:** The muscle is hooked, dissection completed and the faden distance measured from the limbus with the aid of a Scott ruler. A 5–0 polyester suture is passed through the muscle on either side to include at least 25% of the muscle, then the needle is passed through the sclera and the suture tied tightly.

**Faden suture with recession:** The muscle is hooked and dissected completely. The faden distance is marked on the muscle (calculated as faden distance measured from muscle insertion minus recession distance). The muscle is disinserted and a Desmarre’s retractor used to retract the muscle. The faden distance is marked on the sclera and a single 5–0 polyester suture passed through the sclera at this distance. It is then brought out through the muscle at the distance marked on the muscle. Recession proceeds as usual. After anchoring the muscle to the sclera, the faden suture is tied. For further details, readers are advised to refer any textbook on strabismus.
Inactivation of the lateral rectus has been tried for third nerve palsy. The lateral rectus is secured to the orbital periosteum with the help of nonabsorbable 5–0 polyester suture. The orbital periosteum is exposed by blunt dissection a few millimeters posterior to the lateral orbital rim. Medial rectus resections after this procedure may be effective in correcting the deviation in primary position as there is no opposing force now.

**STRENGTHENING PROCEDURES**

Resections are by far the most commonly done procedure to strengthen the muscle. Briefly the procedure consists of isolating the muscle, excising a portion of the muscle comprising primarily of the tendinous portion (starting from the insertion) and suturing the remaining muscle to the insertion in effect tightening the muscle. 6–0 vicryl is used for this procedure. After isolating the muscle, the resection distance is marked with calipers and the sutures passed from inside out (one at each end as shown in figure). The sutures are tied with a squared 2–1–1 knot. While marking the resection distance with calipers, care should be taken not to stretch the muscle, which results in less than intended resection. While passing the sutures, 50% of the muscle is included in the suture. The two sutures are passed at either end of the insertion and tied. Redundant muscle tissue is then excised with Wescott scissors, again taking care not to cut the sutures. Any sedge in the center should be corrected by passing another suture in the center. For lateral rectus resections, it is important as mentioned earlier to sever the attachment to the inferior oblique else a J shaped deformity with resultant vertical deviations will result. In cases of medial rectus resections, the anatomy of the plica should be preserved,
otherwise will result in an unacceptable cosmetic appearance postoperatively.

Muscle advancement can be employed for previously recessed muscles. Generally it is held that each millimeter of advancement gives the same effect as resection. Non-absorbable sutures can be used if the surgeon fears muscle slippage. All measurements are taken from the limbus.

To sum up, horizontal rectus muscle surgery is a relatively simple and straightforward surgery. There are a few points to watch out other than the complications detailed in the earlier chapter. It is preferable for the surgeon to locate the muscle before placing the conjunctival incision especially for patients operated under general anesthesia. This avoids accidental muscle injury. Dissection should always be under direct visualization. For the lateral rectus dissection should be meticulous along the inferior border to avoid distorting inferior oblique anatomy. For reattaching the lateral rectus in recessions at distances of 8–10 mm, it is useful to remember that the fovea is located directly beneath and perforations in this area can be disastrous. The vortex veins are rarely encountered in horizontal rectus surgery. Muscle slippage is rare but needs to be watched out for. The medial rectus is the most common muscle to slip and the most difficult to retrieve. This is because of its short arc of contact and lack of attachments to the oblique muscles. Meticulous attention to principles and technique usually results in a gratifying outcome.

**BIBLIOGRAPHY**

STEPS IN ISOLATING HORIZONTAL RECTI AND RECESSION

Department of Pediatric Ophthalmology
Aravind Eye Hospital
Madurai, Tamil Nadu, India
Fig. 1: Limbal incision made with Wescott scissors in the desired quadrant (in this case left eye medial rectus)

Fig. 2: Relaxing cuts given at one end of the incision
**Fig. 3:** Relaxing incision given on the other end too

**Fig. 4:** Tenon's buttonholed on either side by blunt dissection
Fig. 5: The Von Graefe hook slides in the button hole to hook the muscle in a clean sweep

Fig. 6: The check ligaments are cut close to the muscle (arrow)
Fig. 7: The intermuscular septa (arrow) are cut on either side.

Fig. 8: Locking stay sutures placed on either end of the muscle.
**Fig. 9:** Muscle cut close to insertion in front of stay sutures in small snips

**Fig. 10:** Recession distance marked on the sclera with Vernier calipers measuring from either end of insertion
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Fig. 11: Bites taken at the marks

Fig. 12: Muscle anchored to sclera with locking knots
Fig. 13: Conjunctiva secured with 8-0 vicryl.
STEPS IN RESECTION

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**Fig. 1:** Muscle cleared of Tenon’s till 10 mm from insertion

**Fig. 2:** Resection distance marked on the muscle with Vernier calipers
Fig. 3: Locking bites taken and muscle secured at resection distance

Fig. 4: Muscle secured at either end with 6-0 vicryl
**Fig. 5:** Muscle cut at insertion

**Fig. 6:** Sutures passed through either end of the insertion
**Fig. 7:** 2-1-1 reversing knots placed at either end

**Fig. 8:** Redundant muscle tissue (arrow) excised
Fig. 9: Muscle secured to the insertion

Fig. 10: Conjunctiva secured with 8-0 vicryl
INTRODUCTION (FIG. 8.1)

A vertical deviation (vertical misalignment of the visual axes) may be comitant or incomitant. Either form of vertical deviation can occur or associated with a horizontal deviation. Such an association is the more typical setting for comitant vertical deviation. Majority of the vertical deviations are incomitant. They are associated with so-called overactions or underactions of the superior and inferior oblique muscles, paralysis or contracture of one or more of these cyclovertical muscles or restriction of vertical movement. Although nearly every vertical paralytic deviation is incomitant at onset, it may be with time approach comitance, unless there are associated restrictions.

Fig. 8.1: Extraocular muscle anatomy
A vertical deviation is described according to the direction of the vertically deviating non-fixing eye. In cases of alternate fixation with equal dominance, the deviation is named for the usually hyperdeviating eye in ordinary visual circumstances.

This chapter deals with the various surgical procedures involved in tackling the vertical and oblique muscles.

**VERTICAL RECTUS RECESSION**

**Superior Rectus**

*Indications*
- Dissociated vertical deviation
- Superior oblique palsy with muscle sequelae.

*Technique*

The superior rectus is attached to the levator palpebrae superioris above and the superior oblique below by means of facial connections. Improper dissection can result in upper lid retraction due to the pull caused by the superior rectus. A proper dissection of the upper lid attachments from the superior rectus is very important to avoid upper lid retraction. Dissection should not include the Tenon’s capsule lest it can cause fat adherence to the muscle and result in restricted movements postoperatively.

**Inferior Rectus**

*Indications*
- Monocular elevation deficit
- Superior oblique palsy with muscle sequelae.
Technique

Inferior rectus muscle is attached to the lower eyelid by means of facial attachments. The lower lid retractors, also known as the capsulopalpebral system, interconnect the inferior rectus, inferior oblique and the lower eyelid. This is a continuous musculotendinous tissue which arises from the inferior rectus posteriorly to the inferior oblique muscle and then continues anteriorly to get inserted to the lower tarsal plate. Lockwood’s ligament, which surrounds the inferior oblique muscle, connects the tarsus to the inferior rectus. Inferior rectus recession can lead to lower lid retraction due to pull on the Lockwood’s ligament. Posterior dissection for 10 to 15 mm along the inferior surface of the inferior rectus muscle can help minimize postoperative lower eyelid retraction. But this technique can result in fat adherence to the muscle which can restrict movements. Disinsertion of the lower lid retractors is another very good option to tackle this problem.

Lower lid retractor disinsertion is a very simple procedure. The lower lid is everted using a Desmarres retractor after passing a 4-0 silk stay suture through the lower lid margin. The lower lid retractors insert at the inferior border of the lower tarsal plate. They can be removed using a coagulation mode of a Colorado needle. Pass the Colorado needle 1 to 2 mm below the inferior border of the lower tarsus to burn through the conjunctiva and the underlying lower lid retractors. This has to be done for the entire breadth of the tarsal plate.

Complications

Fat adherence to the muscle can result in restricted movements. Care has to be taken to avoid dissecting the Tenon’s capsule to avoid this complication. Other usual
Vertical and Oblique Muscle Surgery

complications include overcorrection, undercorrection and globe perforation while taking the scleral suture.

OBLIQUE MUSCLE SURGERY

Inferior Oblique Weakening Procedures (Figs 8.2 and 8.3)

Historically, inferior oblique muscle surgery was considered extremely difficult and loaded with complications, such as fat adherence, ciliary nerve damage, pupillary dilatation and hemorrhage. The late Dr Marshall Parks pioneered various techniques that eliminated most of these complications. The inferior oblique muscle also passes a lot of vortex veins in its course around the eye.

Fig. 8.2: Inferior oblique surgery. (Courtesy: Eugene Helveston)
Quantification

Inferior oblique overaction is clinically quantified on a scale of 1 to 4, on version testing, the abducting eye is made to fix the target so that the adducting eye is free to manifest any overactions. Quantify the overaction by keeping the fixing eye horizontally near the lateral canthus. The adducting eye can be prevented from taking up fixation by placing an occluder or the thumb and looking behind the occluder. The quantification is done as follows:

- **1+:** The limbus of the adducting eye is barely seen. Overaction becomes more evident when the abducting eye is moved up and out.
- **2+:** Upshoot is readily evident when the abducting eye is in horizontal gaze itself.
3+: Severe upshoot where the inferior sclera of the adducting eye is visible when the abducting eye is in horizontal gaze position.

4+: Very severe upshoot where the adducting eye moves upwards as the abducting eye is moved laterally. In addition to the upshoot, the adducting eye also shows some abduction as it goes into the field of action of the inferior oblique.

Inferior oblique overaction produces a V-pattern – Y – subtype, with most of the divergence occurring from primary position to upgaze. The final quantification is based on the combined characteristics of the upshoot and the amount of V-pattern.

**Indications for Surgery**

- More than 2+ overactions
- 1+ overaction with significant V-pattern

Primary inferior oblique overaction is usually bilateral and almost always requires bilateral surgery. Bilateral surgery should be performed even in patients with asymmetric overactions. Unilateral surgery can be considered only in patients with unilateral amblyopia, wherein the sound eye takes up fixation always and will not manifest an upshoot.

**Contraindications**

Patients with V-pattern strabismus without inferior oblique overaction should be managed by muscle transposition procedures. Apparent overactions may be seen in patients with craniofacial syndromes, but orbital and other anatomic abnormalities are usually evident radiographically.
**Technique**

*Capturing the Muscle*

The incision is made in the bulbar conjunctiva and intermuscular septum in the inferotemporal quadrant 7 mm to 9 mm from the limbus, which provides an excellent approach to the muscle and causes minimal postoperative discomfort.

The inferotemporal limbus is grasped with a toothed forceps by an assistant to rotate the globe in extreme elevation and adduction. The conjunctival incision is made 8 mm from the limbus in the inferotemporal quadrant. Tenon’s fascia is cut perpendicular to the conjunctival incision. The lateral rectus is secured with a muscle hook. A flat iris spatula is used under direct visualization to dissect the facial attachments of the inferior oblique muscle to the globe. A muscle hook is positioned under the belly of the inferior oblique muscle. Care must be taken to avoid injury to the vortex vein, which may result in extensive bleeding. The muscle is then freed from the surrounding fat with Wescott scissors. Connective tissue attachments to the lateral rectus are freed. Adhesion between the inferior oblique and sclera are freed. When isolating the inferior oblique insertion area, the surgeon must be aware of the possibility of multiple congenital insertions. The inferior oblique is attached very close to the area of macula and the papillomacular fibers of the retina. Surgeons should therefore, exercise extreme caution to prevent damage to the underlying sclera in this region.

**MYOTOMY**

After the muscle is isolated, the surgeon simply incises the tendon at its insertion and allows the muscle to retract.
This procedure may be self-adjusting in the sense that a highly overacting muscle will retract more than a lesser overacting one. Nevertheless, it is very difficult to predict the results in this procedure.

**MYECTOMY (FIG. 8.4)**

Two clamps are placed across the muscle 4 to 8 mm apart. The muscle between the clamps is excised, and the muscle stumps on the clamps are cauterized to prevent hemorrhage or possible reattachment to the sclera after the clamps are released. The surgeon should make sure that no muscle strands connect the muscle ends. A unilateral myectomy will correct 5 to 20 PD of hypertropia.

**Fig. 8.4:** Inferior oblique myectomy. (Courtesy: Eugene Helveston)
Reoperation of the muscle may be difficult after myectomy with cauterization, because relocating the muscle may be difficult.

**RECESSION (FIG. 8.5)**

In a true recession, the entire muscle insertion is receded along the anatomic course of the muscle and reattached to the sclera with one or more sutures. This definition is extended in case of the inferior oblique muscle. A maximum recession (12 to 14 mm) of the inferior oblique muscle places its anterior border 4 mm behind the temporal insertion site of the inferior rectus muscle. Care must be taken to avoid injury to the vortex vein.

Graded recessions ranging from 6 to 12 mm are done for greater or lesser degrees of inferior oblique overactions. The 8 mm recession of Parks is in truth not a pure recession. Scheie-Parks point is a point 2 mm lateral and 3 mm posterior from the lateral point of inferior rectus insertion. Placing the inferior oblique insertion at this point results in anteriorization by 1 to 1.5 mm. Probably, due to this reason, the Parks recession, actually is a more powerful weakening procedure than the 12 mm recession.

Fig. 8.5: Inferior oblique recession. (Courtesy: Pradeep Sharma)
ANTERIORIZATION

The anteriorization is achieved by placing the inferior oblique insertion anywhere anterior to its natural course. In practice, the rectus muscle is used for reference.

Pure anteriorization involves placing the inferior oblique muscle insertion just below the lower border of the lateral rectus muscle. This procedure is useful in cases of mild to moderate overactions.

In the more common procedure, the inferior rectus is secured with a muscle hook after isolating the inferior oblique. The anterior fibers of the inferior oblique are sutured to the sclera temporal to the inferior rectus insertion. The posterior fibers are then bunched up towards the anterior fibers, using a needle passed through the sclera about 1mm temporal to the first needle pass. If the new insertion of the inferior oblique is spread out laterally, there is an increased chance of restricting elevation.

Complications

Fat adherence syndrome: Excessive removal of adipose tissue can result in hemorrhage and subsequent scarring in the inferotemporal quadrant. This scarring can pull the eye downward or restrict upgaze. This may result in unilateral hypotropia. This complication is more common after myectomy than other procedures.

Excessive hemorrhage from the highly vascularized IO muscle can rarely lead to proptosis due to bleed into the orbit. Damage to the vortex vein can also contribute to the hemorrhage.

Undercorrection and overcorrection can occur as with any squint surgery.
SUPERIOR OBLIQUE PROCEDURES (FIG. 8.6)

Parks first described a temporal approach to directly visualize the superior oblique muscle in 1970. The various procedures that are currently done include tenotomy, tenectomy, partial posterior tenectomy, tendon expanders and the tuck.

TENOTOMY AND TENECTOMY

Superior oblique tenotomy and tenectomy are the most common weakening procedures done for the muscle.

Indications
- Brown’s syndrome
- A-pattern strabismus
- Inferior oblique palsy with superior oblique overaction
- Superior oblique myokymia

Fig. 8.6: Superior oblique surgery. (Courtesy: Eugene Helveston)
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The procedure can correct up to 20 PD of A-pattern in primary gaze. Patients with bifoveal fixation may develop torsional diplopia after this procedure. It should not be performed in patients with both superior and inferior oblique overaction.

**Technique**

The conjunctiva is incised in the superonasal quadrant 8 mm posterior to the limbus. The incision is enlarged 6 mm circumferentially. The superior oblique can be visualized by placing a muscle hook on the posterior part of the incision. Care must be taken to avoid injury to the vortex vein. Under direct visualization, the superior oblique tendon is either divided (tenotomy) or a portion is removed (tenectomy). The complete width of the tendon should be cut. Incomplete procedure may not yield the desired results. Forced duction testing is done to confirm the absence of restriction in Brown's syndrome.

**Complications**

Iatrogenic superior oblique palsy is a commonly encountered complication. It has been reported in 30 to 85 percent of cases. Intractable diplopia caused sometimes due to this may be alleviated only by rejoining the cut ends using a silicon spacer.

**POSTERIOR TENECTOMY OF THE SUPERIOR OBLIQUE**

The anterior fibers of the superior oblique are responsible for the torsion and the posterior fibers are responsible for depression and abduction. This procedure selectively
weakens the depression and abduction effects of the superior oblique while preserving its torsional effects. This was first described by Prieto-Diaz in 1976.

**Indications**

- Moderate A-pattern strabismus (up to 20 PD) with superior oblique overaction.
- Incomitant dissociated vertical deviation with superior oblique overaction and A-pattern.

**Technique**

The globe is rotated downwards with the help of a stay suture. An incision is made in the superotemporal quadrant of the bulbar conjunctiva 8 mm posterior to the limbus and extended circumferentially by 6 mm. The superior rectus muscle is secured with a muscle hook. The posterior lip of conjunctiva is retracted with a Desmarres retractor. The superior oblique tendon is isolated with a muscle hook under direct visualization at its insertion. The lid speculum is then removed to improve the field of visualization. Care is taken to include the entire width of the tendon. The superior oblique fibers are then cut at its insertion leaving behind the anterior 2 mm. A quadrilateral portion of the posterior muscle tendon including at least 10 mm of length is then cut and removed. The conjunctiva is closed with interrupted 6-0 vicryl sutures.

**SUPERIOR OBLIQUE EXPANDER (FIG. 8.7)**

This procedure, first described by Wright, involves expanding the superior oblique tendon using a silicon spacer. The weakening effect is graded by varying the length of the expander.
Indications

- A-pattern strabismus with superior oblique overaction
- Brown's syndrome
- To correct iatrogenic superior oblique palsy following tenotomy/tenectomy.
  This procedure can correct up to 20 to 50 PD of A-pattern.

Fig. 8.7: Superior oblique expander. (Courtesy: Eugene Helveston)
The globe is rotated downwards with a stay suture. A conjunctival incision is made in the superotemporal quadrant 8 mm posterior to the limbus and extended 6 mm circumferentially. The superior rectus muscle is isolated on a muscle hook. The opening in the conjunctiva is reflected on the open end of the muscle hook nasally. The superior oblique tendon is identified on the nasal border of the superior rectus. The nasal intermuscular septum should be preserved maximum possible, which will form a sheath over the expander.

A double armed 6-0 non-absorbable suture is woven through the tendon and locked on each end 1 to 2 mm nasal to the superior rectus border. A similar suture is woven 2 mm from the first and the superior oblique tendon is cut in between the sutures. Care must be taken to cut the entire width of the tendon.

A silicon band used for scleral buckling surgery is soaked in antibiotic solution, rinsed and trimmed according to the desired length. The length is decided according to the amount of overaction or A-pattern. A 6 to 7 mm expander is recommended for Brown syndrome. Each non-absorbable suture is passed through the entire thickness of the silicon band. The sutures are tied on the band tightly securing the cut ends of the superior oblique tendon to each end of the band. The conjunctiva is closed with interrupted 6-0 vicryl sutures.

This procedure can be very successful and cause least complications if performed skillfully.
Vertical and Oblique Muscle Surgery

SUPERIOR OBLIQUE TUCK

This procedure is indicated in cases of superior oblique palsy, but its efficacy in complete palsies is questionable. It is recommended in cases of incomplete palsies.

Technique

A lid speculum is inserted and the globe rotated down with a stay suture. A conjunctival incision is made similar to the above procedures. The superior oblique tendon is exposed through a temporal approach. Care must be taken to include the entire width of the tendon on the lateral border of the superior rectus.

A marking suture can be used to tag the entire width of the tendon. The desired amount of tuck is measured with a caliper. The tuck is done temporal to the superior rectus by suturing the proximal and distal points of the tendon using non-absorbable sutures. The conjunctiva is closed with interrupted 6-0 vicryl sutures.

Iatrogenic Brown syndrome is the most common complication following superior oblique tuck, occurring in 17% of patients. Excessive restriction or intolerable torsional diplopia should be treated in the immediate postoperative period by releasing the tuck.

BIBLIOGRAPHY

Chapter 9

Strabismus Surgery in Special Situations

Kalpana Narendran
INTRODUCTION

This chapter will elucidate in brief the evaluation and surgical management of special situations in strabismus. The topics covered would include:

- Nonresolving paralytic strabismus—3,4,6 nerve palsy
- Restrictive strabismus—surgery in:
  - Duane's syndrome
  - Brown's syndrome
  - Moebius syndrome
  - Congenital fibrosis syndrome
  - Dysthyroid ophthalmopathy
  - Postcchalr buckling
  - Blow out fracture.
- Other special situations:
  - Strabismus after local anesthetic injection
  - Strabismus in high myopia.

Nonresolving Paralytic Strabismus

The need to intervene in a case of long-standing and non-resolving paralytic strabismus is to:

- Alleviate diplopia
- Treat abnormal head posture
- Treat strabismus
- To increase the binocular diplopia free field of vision.

Apart from routine preoperative evaluation including assessment of visual acuity, detailed orthoptic work-up (motor and sensory), anterior segment and fundi evaluation, a few other important tests required include:

- Diplopia charting: Provides a record of separation of diplopic images in the 9 gazes, shows areas of single vision and diplopia, Crossed/uncrossed diplopic images, presence of image tilt.
Hess charting: Invaluable in assessing progress, planning treatment and evaluating results. It shows underacting and overacting muscles and muscle sequelae. This is a permanent record and reveals even small limitation of movement at 30 degrees.

Forced duction test: Used to distinguish between defective movement of an eye from mechanical restriction and that due to weakness of the muscle primarily responsible for the movement of the eye to that gaze position.

Active force generation test: Used to distinguish between partial palsy and complete paralysis of muscle and also helps in assessing muscle recovery.

Binocular field of vision.

Evaluation of ocular torsion by objective and subjective methods.

Detailed neurological evaluation: Especially important in deteriorating or progressive condition, younger patient, presence of pupil involvement, aberrant regeneration, nystagmus or any other neurological signs/symptoms.

Pearls before Planning Surgery

- Determine the stability of ocular deviation for at least 6 months.
- Repeat:
  - 9-gaze deviations
  - Diplopia charting
  - Hess/Lees charting
  - Binocular fields of fixation.

At 6 weekly or bimonthly intervals, till the time two consecutive visits show no progression or change.

- Rule out central fusion disruption before attempting surgical correction to avoid intractable diplopia postoperatively especially in post-traumatic nerve palsies.
Surgery in Sixth Nerve Palsy

The surgical plans would vary based on whether it is a case of partial palsy or complete sixth nerve paralysis. Always remember to do forced duction test to identify medial rectus muscle contracture before, during and after the surgical procedure.

**Partial Paralysis**

In partial palsy preoperative force generation test would show some amount of residual lateral rectus function.

- Medial rectus recession
- Lateral rectus resection
- Combined recess-resect procedure (R&R)
  - This is the most commonly done procedure.
- R&R and contralateral medial rectus recession
  - This is done if the deviation in primary gaze is more than 40 PD.

**Total Paralysis**

The surgical goal in a case of total sixth nerve palsy is to try to create an abducting force and to increase the binocular diplopia free field of vision. A muscle transposition procedure would be the surgery of choice. These include:

- Partial vertical recti transposition to insertion of lateral rectus (Hummelscheim) + Medial rectus weakening by recession or botulinum toxin (Figs 9.1A and B).
  - This includes splitting of the vertical recti muscles, cutting the temporal halves and attachment near the lateral rectus muscle insertion.
- Full tendon vertical recti transposition + Medial rectus weakening.
  - The entire superior and inferior recti are cut at their insertion and reattached near the insertion of lateral rectus (Figs 9.2A and B).
Figs 9.1A and B: Partial tendon transposition. (Courtesy: Pradeep Sharma)

Figs 9.2A and B: Full tendon transposition. (Courtesy: Pradeep Sharma)

- Foster’s augmentation of transposition procedure includes placement of a posterior fixation suture which improves abduction further.
- Recti muscle union (Jenson’s) + Medial rectus weakening

  In this procedure, after splitting the superior, inferior and lateral recti muscles, the temporal half of SR and upper part of LR and the temporal part of the IR and the lower half of LR are tied together with the help of nonabsorbable suture material (Figs 9.3 and 9.4).
In individuals who are at a higher risk for anterior segment ischemia, e.g. older people with microvasculopathy, the above procedures can be done using the ciliary vessel sparing technique.
Surgery in Third Nerve Palsy

Partial Third Nerve Palsy
The goals of surgery include good motor alignment, to relieve diplopia and to broaden the field of binocular single vision.

- **Isolated muscle involvement:** The paretic muscle with residual function is resected and its antagonist is recessed, preferably with adjustable suture.
- **Multiple muscle involvement:** Management strategy depends on which muscle action is more affected, e.g., in paralysis of inferior division of third nerve, Knapps suggested transposition of superior rectus to medial rectus and lateral rectus to inferior rectus. Tenectomy of the superior oblique may be included if there is significant intorsion.

Total Third Nerve Paralysis
The goal of surgery is realignment in primary position. As no significant area of single binocular vision is achieved, surgery is mainly performed in cases of congenital third nerve palsy with amblyopia, to achieve better cosmesis. Acquired third nerve paralysis is better left untreated as there is a high-risk of intractable diplopia following surgery.

Various Surgical Strategies (Figs 9.5 and 9.6)

- Fixate the globe (MR muscle insertion) to MPL insertion at anterior lacrimal crest using nonabsorbable 5-0 polyester sutures + large LR recession in congenital total 3rd nerve palsy (P Sharma et al, JAPOS 2006, P Vijayalakshmi et al, JAPOS 2004).
- Superior oblique tendon resection and transposition to the area between MR and SR insertion (Figs 9.5A and B).
Figs 9.5A and B: Superior oblique tendon. Surgical strategy for total 3rd nerve palsy. (Courtesy: Clinical Strabismus Management Rosenbaum)

- Hemi-hangback recession of LR and resection of MR. Depending on the magnitude of vertical deviation, the insertions of the horizontal rectus muscles were moved upward, alone or in combination with hemi-hangback recession IR (Courtesy: Köse S, Uretmen O, Pamukçu K. Strabismus 2001;9(1):1-8)
Adducting traction sutures combined with large recess-resect of the horizontal rectus muscles are safe and effective in the management of long-standing strabismus due to third nerve palsy. (Courtesy: Khaier A, Dawson E, Lee J. Strabismus 2008;16(2):77-83)

Full correction of ptosis can result in risk of corneal exposure if Bell’s phenomena is poor. Hence undercorrection is preferred.
Squint Surgery

Surgery for Fourth Nerve Palsy
(Figs 9.7A and B and Flow Chart 9.1)

In the case of bilateral fourth nerve paralysis, most commonly seen following closed head trauma:

- If extorsion < 10°, then inferior oblique recession on one or both sides and bilateral inferior rectus recession (Fig 9.7A).
- If extorsion > 10°, bilateral Harada Ito procedure which is splitting and advancement of the anterior half of the superior oblique tendon (Fig. 9.7B).

Figs 9.7A and B: Surgery in fourth nerve palsy. (Courtesy: Clinical Strabismus Management, Rosenbaum)
Flow Chart 9.1: Surgery in fourth nerve palsy (Courtesy: Clinical Strabismus Management, Rosenbaum)

Traction test

Absent tendon
- Recess SR
- Weaken IO

Markedly lax
- Tuck so to match "Normal" side
- Weaken IO

Everyone else (Including acquired unilateral)
- IO overaction?
  - Yes
  - HT < 15 pd
    - Yes
    - Weaken IO
    - No
    - SR Restriction?
      - Yes
      - Contralateral IR recess
      - No
      - Contralateral IR recess
  - No
  - HT < 15 pd?
    - Yes
    - Contralateral IR recess
    - No
    - IPSILAT SR recess

Recess SR
- Weaken IO

Recess IR (Contralateral)
- Weaken IO
RESTRICTIVE STRABISMUS

Surgery in Duane’s Syndrome

Indications for Surgery

- Significant misalignment in primary position
- Significant head posture with poor cosmesis (Fig. 9.8)

Fig. 9.8: Compensatory head posture in DRS

Fig. 9.9: Narrowing of palpebral fissure in DRS
Strabismus Surgery in Special Situations

- Narrowing of palpebral fissure due to retraction (50% or more) (Fig. 9.9)
- Significant upshoot or downshoot (Fig. 9.10)

**Fig. 9.10:** Significant upshoot in DRS

Adequate counseling to the patient is very essential to make them understand that surgery will not improve ocular rotations in all gazes.

Avoid resection of the lateral rectus muscle as it increases the globe retraction.

**Esotropic Duane’s (Fig. 9.11)**

- For significant face turn (same side)—recession of ipsilateral medial rectus.
- Eso DRS with cocontraction—Asymmetric recession of both ipsilateral medial and lateral rectus to counteract esotropia in primary position.

**Fig. 9.11:** Esotropic Duane’s
Transposition of vertical recti to the insertion of lateral rectus has been tried by few authors (Fig. 9.12).

**Fig. 9.12:** Transposition of vertical recti

- For large angle esotropia—bimedial recession.
- Posterior fixation suture on the normal medial rectus may diminish adduction innervation slightly in the involved eye making the esodeviation in the involved side less (Fig. 9.13).

**Exotropic Duane’s (Fig. 9.14)**

- For significant face turn (opposite side)—recession of ipsilateral lateral rectus
  - Also corrects moderate globe retraction, mild upshoot/downshoot
Strabismus Surgery in Special Situations

- For significant upshoot/downshoot—recession with Y-splitting of lateral rectus
- For large exotropia—bilateral recession
- Significant globe retraction—asymmetric ipsilateral recession of medial and lateral recti.

Fig. 9.14: Exotropic Duane's

Orthotropic Duane's (Fig. 9.15)

- For significant upshoot/downshoot—Y-splitting of lateral rectus,

Fig. 9.15: Orthotropic Duane's

- Significant globe retraction—ipsilateral recession of medial and lateral recti (Fig. 9.16).

Fig. 9.16: Significant globe retraction
Surgery in Brown’s Syndrome (Fig. 9.17)

Spontaneous resolution has been reported to occur sometimes even in the true congenital Brown’s cases and more commonly in acquired cases or intermittent types. Hence, surgery in patients with acquired or intermittent Brown’s should be avoided until the underlying disease has been controlled medically, and the syndrome persists and meets the surgical criteria as outlined here.

**Indications for Surgical Intervention**

**Absolute indication**

Severe and constant congenital case that threatens loss of binocularity if left untreated.

**Relative indications**

- Hypotropia in primary position
- Head posture which is cosmetically significant
- Significant downshoot
- To expand binocular diplopia free fields.

*Fig. 9.17: Brown’s syndrome*
Strabismus Surgery in Special Situations

Surgical Techniques

- Initially tenectomy and tenotomy of the superior oblique tendon were the procedure of choice. This was done using a superonasal conjunctival incision, isolating the superior oblique tendon and cutting it in tenotomy or cutting a length of it in tenectomy.
- Parks recommended recession of the inferior oblique muscle at the same sitting to avoid overaction of the same postoperatively.
- To reduce the risk of postoperative superior oblique palsy, Wright introduced the controlled weakening procedure in which a segment of silicone band is sutured between the cut ends of the tenotomized muscle. The length of the silicone band can be chosen based on the amount of weakening desired.
  The most common complication following surgery for Brown’s syndrome is iatrogenic superior oblique palsy.

Surgery in Moebius Syndrome (Fig. 9.18)

This congenital condition is characterized by bilateral abducens nerve palsy with facial diplegia, along with craniofacial, skeletal, cardiac and muscular anomalies.

The surgical management in this condition is complex and multifactorial. In many cases optimal postoperative alignment may be possible only in primary gaze.

Perform forced duction test to identify a tight medial rectus muscle.
- If FDT is negative, then bilateral vertical recti transposition to lateral rectus is adequate
- If FDT is positive, then vertical recti transposition to lateral rectus is followed by staged medial rectus weakening.
**Problems Encountered**

- **Preoperative evaluation:** Epicanthal folds, difficulty in speech
- Anesthesia—difficult intubation
- Hypoplasia, aplasia, fibrous bands or abnormal muscle insertions
- Poor postoperative wound healing due to lagophthalmos and inadequate blink mechanism.

**Surgery in Congenital Fibrosis Syndrome**

**Harley’s Classification**

- Generalized fibrosis
- Fibrosis of the inferior rectus with blepharoptosis
- Strabismus fixus
- Vertical retraction syndrome
- Congenital unilateral fibrosis.

**Fig. 9.18:** Moebius syndrome
Surgical Goals
- Alleviate chin-up posture
- Align eye in primary position
- Remove obstacles to visual axis in primary gaze.

Procedure
Large recessions of the extraocular muscles are preferred with conjunctival recession. Forced duction test should be done both pre- and intraoperatively to assess if the restriction has been adequately removed.

Surgery in Thyroid Ophthalmopathy (Figs 9.19 A and B)
This occurs more frequently in middle aged women, and ocular myopathy does not necessarily reflect the state of thyroid activity. Hypotropia with limited elevation is the most common motility abnormality seen.

Goal of Surgery
To align the eyes in primary gaze and reading position with some increase in the range of rotation.

Pre-requisites
- Deviation should remain constant for at least 6 months.
- Surgery should be delayed in the presence of anterior inflammatory signs.
- Orbital decompression, if needed, should be done prior to strabismus surgery.

Technique
Intraoperative FDT should be done before and after surgery. Care should be exercised while hooking a tight inferior rectus to avoid scleral perforation. Conjunctival recession can be added. Adjustable sutures can be used. Avoid resections.
Squint Surgery

Complications
Over and undercorrections, lower lid retraction, late slippage of inferior rectus.

SURGERY AFTER SCLERAL BUCKLING PROCEDURE

Mechanisms for Heterotropia

Mechanical Factors
- Adhesions
- Buckle effect.

Figs 9.19A and B: Thyroid ophthalmopathy
Anatomical Factors
- Nerve damage
- Macular Ectopia/Gliosis.

Sensory Factors
- Breakdown infusion
- Sensory deprivation
- Aniseikonia
- Anisometropia.

Muscle Factors
- Muscle ischemia
- Direct Trauma
- Disinsertion
- Muscle slip.

Preoperative Considerations
- FDT—to analyze degree of muscle restriction present
- Contribution of buckle—if identified as a major factor contributing to strabismus, then decision to remove part of it should be made in consultation with the retina surgeon.

Approach to Surgery
A limbal conjunctival incision is preferred for better exposure. Adhesions are meticulously released. Only enough buckle is excised to allow the muscle to reattach to the globe. Conjunctiva may be recessed at the ends if significant restriction is present. Adjustable suture techniques may be used.
Complications

- Redetachment
- Implant migration and extrusion
- Persistent diplopia.

Surgery after Blowout Fracture
(Figs 9.20A and B and Flow Chart 9.2)

Flow chart 9.2: Surgery after blowout fracture
Mechanisms of Strabismus after Blowout Fracture

- True entrapment of IR
  - If posterior to equator—depression restriction
  - If anterior to equator—elevation restriction.
- Entrapment of fibrous orbital septa
  - Resulting in EOM restriction
  - Injury to an EOM or its innervations
  - Resulting in paresis without restriction.

Treatment

**Orbital Fracture**

- Rule out damage to globe and optic nerve
- Oral antibiotics and prednisolone for 2 weeks
- Surgical repair is indicated if:
  - Fracture >50% of orbital floor
  - >2 mm of enophthalmos
  - IOP elevation > 45 mm Hg in upgaze indicating entrapment.

**Of Strabismus**

- IR restriction with hypotropia
  - IR recession +/- adjustable sutures
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- IR palsy:
  - If partial—IR resection or SR recession
  - If complete—horizontal recti transposition
- IR palsy + restriction
  Complex surgical management
- MR entrapment
  As for isolated IR restriction.

**Strabismus following Injection of Local Anesthetic**

The inferior rectus is the most commonly affected muscle. Immediately following injection of local anesthetic, there is a transient period of muscle palsy followed by muscle fibrosis.

**Treatment**

- Wait for spontaneous resolution of diplopia for 6 to 8 weeks
- If not resolving then consider surgery to alleviate diplopia.
  Surgical plan would be to recess the overacting inferior rectus muscle—1 mm of recession would correct 3PD of hypotropia.

**STRABISMUS IN HIGH MYOPIA**

**Bilateral Myopia and Esotropia**

This happens as the lateral rectus muscle is displaced inferiorly due to progressive superotemporal elongation of the globe. The altered muscle path can be seen on MRI.
Strabismus Surgery in Special Situations

Treatment

Large recession of medial rectus and to transpose the lateral rectus superiorly by suturing them to the sclera at the equator.

Heavy Eye Syndrome

Very high myopia with severe axial length elongation that causes esotropia and hypotropia with limitation of abduction and elevation due to displacement of lateral rectus inferiorly and superior rectus nasally.

Treatment

To move the displaced muscles back to their original location. The lateral rectus is transposed superiorly and superior rectus temporally and united at the equator with a nonabsorbable suture.

BIBLIOGRAPHY

Chapter 10

SQUINT SURGERY WITH ADJUSTABLE SUTURES

Mihir Kothari
A strabismus surgeon aims to achieve well aligned eyes with good comitance, centralized and expanded field of binocular single vision, highest grade of binocular fusion and stereoaucuity, symmetrical palpebral apertures, corrected head posture and full ocular movements by performing minimum number of squint surgeries and least postoperative discomfort. To achieve the target angle of alignment in the immediate postoperative period, an adjustable suture technique is helpful. Although the adjustable suture technique was described by Harms way back in 1941, it was in 1975 that it became popular after its description in English literature by Jampolsky. Despite of a few reports questioning the superiority of the adjustable suture surgery over the conventional surgery as a routine, reoperation rates have been reduced from 19-35% to 4-10% with the adjustable sutures. Currently, we use this technique routinely for every patient regardless of the cause of the squint and the age of the patient. With adjustment of sutures, we can alter up to 23PD deviation in the postoperative period.

(1) Half bow tie method (Video 8) and (2) Sliding noose method (Video 9) are the two popular methods of adjustable suture squint surgery. Except for the final steps of fixation of the muscle to the sclera, the technique of the conventional/nonadjustable suture technique and adjustable suture technique remain the same. We will describe the final steps of the muscle refixation and the adjustment procedure.

**HALF BOW TIE METHOD** (VIDEO 8)

- The needles are passed angulated at 30-45° to the midline from the insertional stump so that they exit close to each other.
Squint Surgery with Adjustable Sutures

- Care is taken to avoid incorporating any fibrous/Tenon’s tissue to allow smooth postoperative adjustment.
- The muscle sutures are held tight by the surgeon and the assistant holds the sutures with a nontoothed forceps at a desired distance measured from the scleral exit with the caliper.
- A half bow knot is placed over a double overhand tie.
- The muscle is then allowed to fall back.
- The measurements are confirmed and the sutures are trimmed leaving 2-3 cm of length to allow adjustment of the suture later.
- Conjunctiva is closed leaving a loop with a loose 8-0 Vicryl suture to be tied tight after adjustment.
- An interrupted “bucket handle suture” is created that would be used for the adjustment.
- The sutures are tucked under the conjunctiva or left in the fornix or taped to the skin.
- Antibiotic drops are instilled and eye pad is placed.

Postoperative Adjustment of the Sutures

- This is performed on the alert and cooperative patient after 4-24 hours preferably in the operation theater under all the aseptic precautions. In case of a child, it is performed as a single step procedure under general anesthesia (preferably sevoflurane).
- Local anesthesia can be achieved with topical 0.5% proparacaine HCl/2% lignocaine.
- The assistant rotates the eye by holding the bucket handle suture and asking the patient to look in the direction opposite to the muscle action.
- The muscle sutures are identified and held by the surgeon.
If an adjustment is not required, the loop of the bow tie is pulled to square off the knot without opening the knot.

If an adjustment is required, the loop is untied as if it were a shoelace. This will leave the double overhand throw visible. To advance the muscle, the surgeon pulls up the muscle and will cinch down the knot at a new distance, measured by the assistant where he/she holds the suture with a blunt forceps.

The slip knot (half bow tie) is tied again and the cover test is performed once again.

Approximately 2-3PD correction is obtained for 1 mm adjustment.

This process can be repeated as many times as necessary to reach the desired target of correction.

If the muscle needs to be further recessed, the overhand knot is advanced to a new distance, measured by the caliper and the muscle suture held by the assistant with a blunt forceps.

The slip knot (half bow tie) is tied again and the cover test is performed once again.

Approximately 2-3PD correction is obtained for 1 mm adjustment.

This process can be repeated as many times as necessary to reach the desired target of correction.

At the end of the adjustment the loop of the bow tie is pulled to square off the knot and loose conjunctival suture is tied.

**SLIDING NOOSE METHOD**

This is the favored and the recommended method for adjustable suture squint surgery. The adjustment can be performed in the OPD with much higher safety and much
more efficiently than the half bow tie method. If a patient does not need the adjustment of the sutures, the sutures can be left alone without squaring off the knot without the fear of knot slippage.

There is no loose suture over the conjunctiva, there is no bucket handle suture and also the muscle suture is trimmed short, which stays under the conjunctiva; the patient is very comfortable postoperatively.

The technique of sliding noose adjustable suture practiced by us is as follows:

- The needles are passed angulated at 30-45° to the midline from the insertional stump so that they exit crossing the midline or cross each other in the midline (Cross sword technique).
- Care is taken to avoid incorporating any fibrous/Tenon’s tissue to allow smooth postoperative adjustment.
- The muscle sutures are held tight by the surgeon and a single over hand knot is tied as shown. Or the assistant holds the sutures with a nontoothed forceps at a desired distance, measured 5 mm ahead of the desired recession from the scleral exit of the sutures with the caliper.
- While the assistant holds the muscle suture tight, a noose is tied around the muscle suture at the desired distance by the double over throw and then squaring off the knot. One more throw is taken and noose is tightened after confirming the distance with the caliper to avoid unintended sliding of the noose.
- The ends of the noose are trimmed with both the arms of the sutures cut at equal length.
- The muscle is then allowed to fall back.
- The measurements are confirmed and the muscle sutures are trimmed leaving one arm of the muscle suture slightly longer for the later identification.
The sutures are tucked under the conjunctiva and the conjunctival incision sutured.
Antibiotic drops are instilled and eye pad is placed.

**Postoperative Adjustment of the Sutures**

- This is performed on the alert and cooperative patient after 4-24 hours preferably in the examination room under all the aseptic precautions. In case of children, one time adjustment is performed under general anesthesia (sevoflurane).
- Local anesthesia can be achieved with topical 0.5% proparacaine HCl/2% lignocaine.
- The patient to asked to look in the direction opposite to the muscle action.
- The muscle sutures are identified from under the conjunctiva and pulled out (under slit lamp/binocular loop) and held by the surgeon.
- If the recession needs to be reduced, the sliding noose is pushed down while the muscle suture is pulled forward (caution the patient that it will hurt a bit) and if the recession needs to be increased, the noose is pulled out by the desired amount and the patient is instructed to look in the direction of the muscle for the augmentation to take its effect.
- Approximately 2-3PD correction is obtained for 1 mm adjustment and the cover test is performed.
- This process can be repeated as many times as necessary to reach the desired target of correction.
- Once the desired correction is reached, the sutures are simply buried under the conjunctiva and the antibiotic eyedrops are instilled.
Additional Tips

- If adjustable sutures are used in children – one time adjustment is performed under general anesthesia, preferably using sevoflurane anesthesia which is augmented with topical anesthetic, preferably proparacaine HCl 0.5%.
- Instillation of HPMC (viscoelastic) eyedrops makes suture surface smooth and hence the adjustments easy.
- Excessive pulling of the muscle or jerky movements should be avoided for the fear of inciting pain or provoking the oculocardiac reflex.
- Avoid holding of the sutures with the toothed forceps – to prevent suture damage and the breakage of the sutures.
- Cheese wiring of the scleral bites should be avoided by holding the sutures with correct tension and in the right direction.
- Usually never required, however, an emergency tray containing atropine injection should be available for the patients who develop oculocardiac reflex. This is more commonly seen in anxious patients, athletic males and patients who have a history of motion sickness. In such a situation, injection atropine given intramuscularly half an hour prior to the adjustment is helpful.
- Adjustable suture technique is best reserved for the recessions. It can be applied to resections and transpositions.
- Advancement of muscle is usually easier but more painful than increasing the recession, which is less painful but more difficult.
CONCLUSION

Adjustable suture technique of squint surgery requires a few modifications in the final steps of a squint surgery. It provides the surgeon a capability to change the alignment postoperatively in order to achieve targeted alignment. This technique of surgery is easy to learn and master and provides superior results for immediate postoperative ocular alignment.

REFERENCES

Chapter 11

BOTULINUM TOXIN IN SQUINT

Ramesh Murthy
INTRODUCTION

Botulinum toxin has been described as the ‘most poisonous poison’, though now it is one of the most common drugs used in the world especially for cosmetic indications. *Clostridium Botulinum* which produces the toxin was first isolated by Van Ermengem in 1895. This organism is a gram-positive, spore forming, anaerobic rod commonly found on plants, in soil, water and the intestinal tracts of animals and fish. The clinical picture of Botulism was described by Justinus Kerner in 1822. The concept of injecting pharmacological agents into extraocular muscles to paralyze them was first perceived by Dr Conrad Behrens. In 1973, Dr Alan Scott injected the extraocular muscles of rhesus monkeys with different agents including botulinum toxin and subsequently demonstrated the utility of this toxin in humans. Currently botulinum toxin has applications in neurology, dermatology, gastroenterology, orthopedics, otorhinolaryngology and ophthalmology.

PHARMACOLOGY

*Clostridium Botulinum* produces eight different exotoxins (A, B, C1, C2, D, E, F and G). Type A is the most potent and frequently used. These are single polypeptide chains of about 150 kDa weight with an L chain and a H chain joined by disulfide bonds.

PREPARATIONS

There are three commonly available commercial preparations – Botox (Allergan Inc, USA), Dysport (Ipsen Pharmaceuticals, France), both of which are type A and Myobloc which is a type B toxin. Type A toxin is the most
Botulinum Toxin in Squint

potent and is the one currently in vogue. It has the longest duration of action and has a favorable ratio between the biologically active and inactive neurotoxin.

MECHANISM OF ACTION

This toxin acts at four different sites in the body: the neuromuscular junction, autonomic ganglia, postganglionic parasympathetic nerve endings and postganglionic sympathetic nerve endings which release acetylcholine (Ach).

At the neuromuscular junction botulinum toxin causes muscle paralysis. Normally the muscle contraction occurs due to acetylcholine vesicles released into the synaptic cleft. Botulinum toxin when injected, binds to the nerve terminal gets internalized and prevents the release of the acetylcholine vesicles by the inhibition of SNARE proteins. About 8 weeks after the injection, new nerve terminal sprouts emerge and extend towards the muscle surface, reinnervating the muscle.4

The classic rationale given for the use of botulinum to treat strabismus is to induce a temporary paralysis of a normal or overacting muscle, which allows shortening and contracture of the under acting or paretic antagonist of the injected muscle. This in turn produces a change in the alignment of the eyes towards normal with persistence after resolution of the botulinum toxin induced paralysis.

TECHNIQUE OF INJECTION

The toxin is available as a 100 unit or 50 unit vial. Reconstitution is performed with sterile non-preserved 0.9% saline prior to injection. The toxin concentration depends on the volume of diluent used. The dose used in the extraocular muscles varies between 1-5 units. The
solution once reconstituted should be clear, colorless and free of particulate matter and should be stored in a refrigerator at 4° C until use. The reconstituted toxin is drawn into a tuberculin syringe and injected with a fine gauge needle (30 G or 32 G). While it has been mentioned that the toxin needs to be used within 4 hours of injection, the vial once reconstituted can be used up to 4 weeks.

The injection can be given under electromyographic guidance or under direct visualization. After instilling topical anesthetic agents, the injection needle is passed through the conjunctiva into the muscle on the orbital side after turning the eye into the field of action of the muscle to be injected. If using EMG guidance, a needle electrode connected to a tuberculin syringe is used. The electromyographic signal is used as a guide to advance the needle to a point within the muscle and about 2.5 cm to its insertion. The toxin is then injected. If unavailable, direct injection into the muscle can be performed by exposing the muscle with a conjunctival incision.

**CONTRAINDICATIONS TO THE USE OF BOTULINUM TOXIN**

1. Neuromuscular junction disorders:
   a. Myasthenia gravis.
   b. Eaton-Lambert syndrome.
2. Peripheral motor neuron disease:
   a. Amyotrophic lateral sclerosis.
   b. Motor neuropathy.
4. Areas of active infection.
5. Known hypersensitivity to any ingredient in the formulation.
CLINICAL APPLICATIONS

The main advantage of botulinum toxin is it can be performed as an outpatient procedure in adults and can reduce misalignment. The current indications in squint include:

- Paralytic strabismus.
- Postoperative consecutive strabismus.
- Augmentation of transposition effect.
- Active thyroid orbitopathy.
- Cyclic esotropia.
- Previous multiple surgeries.
- Strabismus less than 40 prism diopters.
- Patients who are not suitable for surgery.

In cases like restrictive squints, large angle deviations and over recessed muscles botulinum toxin is ineffective. While the risks are low, problems include multiple repeated injections, temporary improvement, diplopia and or sensory disorientation and temporary overcorrection due to underaction of paralyzed muscle. Globe injury, retrobulbar hemorrhage and changes in eyelid position can occur with periocular injection. Spread of the drug beyond the muscle can lead to partial weakness of the orbicularis and levator muscle and can cause lagophthalmos, ptosis and impairment of Bell’s reflex.

CRANIAL NERVE PALSYES

Acute acquired nerve palsies may improve over time, but chronic palsies are more resistant to cure. Botulinum toxin can prevent muscle contracture in these cases. Children with nerve palsy who do not develop a compensatory head posture may develop amblyopia and lose stereopsis in a few weeks. In cases of sixth nerve palsy botulinum toxin injection can restore fusion and prevent medial rectus
contracture. In some cases of sixth nerve palsies, some surgeons prefer to perform transposition of the vertical recti to the lateral rectus and augment the procedure with botulinum injection to the medial rectus either preoperatively, intraoperatively or postoperatively. Foster type modifications are usually not combined with botulinum augmentation. Nearly 50% patients can be cured with injection and surgery can be avoided.

In the treatment of third nerve palsy, it has limited success. It can be administered if the paresis persists over a 4 weeks period. Some partial third nerve cases respond with botulinum administration, but little benefit is seen in cases of total third nerve paralysis. Multiple muscle involvement limits the use of botulinum in case of cranial third nerve palsies.

For superior oblique palsies, botulinum may improve symptoms. Injections into the inferior oblique are usually performed. Half the patients had improvement in their symptoms for primary and reading positions and resolution of torticollis, but diplopia was not eliminated in lateral gaze positions. Botulinum was most effective when injected into the inferior rectus, when the inferior oblique was injected 83% patients needed surgery.

**VERTICAL STRABISMUS**

In cases of active thyroid disease, patients may benefit with injection of the inferior rectus, though most of the patients will need surgery. The problem with injections to the superior rectus is the ptosis and hence this should be avoided in children in the amblyogenic period. In most cases of hypertropia, injection into the superior rectus alone may not be enough and injection into the inferior oblique may also be needed.
PARADOXICAL DIPLOPIA

This condition occurs when the visual cerebral cortex projection of diplopic images does not correspond to the objective angle of deviation, indicating anomalous retinal correspondence. In cases where inadvertent surgery has been performed and the patient develops intractable diplopia, this may work. We have reported on a case of acquired motor fusion deficiency where the diplopia was relieved after injections of botulinum toxin.8

SENSORY STRABISMUS

Botulinum can be a useful adjunct in these cases. In sensory exotropia, surgeons prefer to operate only on the eye with poor vision if possible. In these cases, botulinum toxin can be an adjuvant treatment.9

NYSTAGMUS

In nystagmus, retrobulbar injection of botulinum has been utilized with the quantity varying from 20-30 units. Sometimes injections into individual extraocular muscles have also been tried. Complication following retrobulbar injections include ptosis. Improvement in vision can help the patients secure a driver’s license. Repeated injections of botulinum toxin may be needed to maintain vision. Botulinum toxin has also been noted to be useful in patients with oscillopsia in a study performed by us on wheelchair bound patients.10

DISSOCIATED VERTICAL DEVIATION

In a study by Ruiz et al, patients with infantile esotropia treated with botulinum injections into both medial recti
before 18 months of age required more injections and had greater dissociated vertical deviation.\textsuperscript{11}

**OPHTHALMOPLEGIA**

Patients with ophthalmoplegia sometimes need multiple surgeries. In these cases, botulinum toxin can be beneficial. It has been shown to be beneficial for patients with external ophthalmoplegia. We have reported on a series of cases of internuclear ophthalmoplegia where subjective benefit was reported by patients with improvement of the quality of the image.\textsuperscript{12}

**HORIZONTAL STRABISMUS**

**Consecutive Strabismus**

One of the potential complications of strabismus surgery is overcorrection. Botulinum toxin has been noted to be helpful in restoring high grade stereopsis in patients with consecutive esotropia with fusion potential.\textsuperscript{13} In a study on children, it was noted that there was successful alignment in children with residual esotropia following strabismus surgery and botulinum toxin injection was comparable to surgery.\textsuperscript{14}

**ESOTROPIA**

Botulinum toxin may be useful in patients with esotropia. For large angle esotropia, it may be combined with medial rectus recessions. In patients with nystagmus, patients had a lower surgical dose and less strabismus surgery. However, multiple treatments are required.\textsuperscript{15} Adults with secondary esotropia, consecutive esotropia, residual
esotropia and primary esotropia are likely to be benefited by botulinum injections.

Botulinum has also been evaluated in infantile esotropia. While the exact benefit of botulinum in infantile esotropia is unclear, it is less effective than traditional surgery.

EXOTROPIA

Botulinum toxin has been used in cases of exotropia. Due to the induced hypertropia, botulinum may not be the best choice. In cases of sensory exotropia in patients where surgery has not been satisfactory, botulinum can be a choice, but multiple injections are necessary. Botulinum can also be used to assess the risk of postoperative diplopia, though prism adaptation poses a lesser risk. Surgery is preferred as the first choice in most patients with exotropia (Figs 11.1A to C).  

Fig. 11.1A: At the end of 6 weeks he was noted to have complete recovery of his ocular movements and resolution of the diplopia
Fig 11.1B: A 47-year-old gentle man presented with sudden onset of left eye third nerve palsy. He was a known diabetic. He presented with ptosis and exotropia. He was treated with an injection of botulinum toxin into the lateral rectus muscle. Improvement in the ocular alignment was noted within 3 weeks.

Fig 11.1C: Improvement in ocular alignment postinjection
REFERENCES

SECTION 3
POSTOPERATIVE CONSIDERATIONS
SQUINT POSTOPERATIVE FOLLOW-UP AND TREATMENT

Milind Killedar
Squint surgery is one of the common surgeries amongst the ophthalmic surgeries. The postoperative follow-up and treatment is not very different from cataract except a few changes.

Although, there is no standard regime which is followed by everyone, the schedule given below can be convenient to follow and would avoid any missouts.

**FIRST POSTOPERATIVE DAY**

Usually the dressing is opened and then clean the eye. A drop of paracaine will make child comfortably open the eyes and gain confidence. Although, in Western world it is a common practice to keep eyes open without a dressing and inform parents about bloody tears, it is not a common practice in India. But if it is bilateral surgery, I prefer to keep one eye open (usually the eye with less no of muscles operated). Keeping both eyes closed makes the child extremely unhappy. After removal of dressing and putting a drop of paracaine wait for ½ to 1 hour and then see the ocular alignment. If it is adjustable suture surgery take 3 readings of ocular deviation at ½ hourly interval. Then plan for readjustment under topical anesthesia or short GA. The child is then given goggles for protection. One should look for corneal abrasions, cells in A/C at this stage.

**One Week Postoperative Follow-up**

By one week, the lid edema subsides and patient can comfortably open the eyes. At this time, I usually advise convergence exercises especially for exotropes. I usually allow all kinds of work, attending school at this follow-up. If the conjunctival sutures are lost and conjunctiva is not retracted much, it can be left alone.
One Month Follow-up

At this time the congestion, subconjunctival hemorrhage is gone. The final alignment can be measured and decision to operate other eye can be taken if necessary. Also tests for binocular single vision and stereopsis should be done. The diplopia which is transient especially after purposefully overcorrected exotropes in adults usually goes by 8 days and surely by one month. If it has not gone, prismotherapy or resurgery can be considered.

POSTOPERATIVE DRUG REGIME

This would consist of local and systemic medicines.

Locally

I usually prescribe steroid antibiotic combinations 4 times a day and a steroid antibiotic ointment once at bed time. If there is a dellen noted, local lubricants can be added.

Systemic

In children I prescribe first generation cephalosporin 25 mg/kg and nonsteroidal anti-inflammatory drug like ibuprofen or nimesulide in appropriate dosage. If the need arises, antiemetics can be given in injectable form on the operative day.
COMPLICATIONS IN SQUINT SURGERY

Prasad Walimbe
As compared with most other kinds of ophthalmic surgery, operating on extraocular muscles in squint surgery rarely results in sight-threatening complications. However, the overall incidence of undesirable results is relatively high. Although, some suboptimal results are influenced by central nervous system input, a substantial number of unsatisfactory postoperative outcomes can be avoided by thorough preoperative evaluation and sound surgical knowledge and technique (Fig. 13.1).

**INTRAOPERATIVE COMPLICATIONS**

**Faulty Muscle Isolation**

Inadvertent surgery on wrong muscle or wrong eye or on only a portion of intended muscle can result in gross sur-

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**Fig. 13.1:** Extraocular muscle insertions and width in mm
Complications in Squint Surgery

Prevention

The surgeon must confirm the identity of patient, the detail surgical plan before surgery.

Hooks used to engage rectus muscle should be positioned with great care. Sweeping even a few millimeters too posterior for lateral or superior rectus may lead to inclusion of IO or SO tendon respectively (Figs 13.2 and 13.3). A very posterior sweep for medial rectus can occasionally hit optic nerve. On the contrary superficial hooking may miss the muscle altogether; this can especially happen in resurgery, when scar tissue is mistaken for muscle.

Fig. 13.2: Inferior oblique muscle
Another possible complication of inferior oblique isolation is damage to ciliary ganglion, causing postoperative mydriasis.

**Hemorrhage**

Hemorrhage during muscle surgery never leads to hemodynamically significant blood loss, but it often interferes with visibility, thereby increasing the risk of other complications and prolonging operating time.

* Conjunctiva: More bleeding may come from transected conjunctival vessels, particularly if incision is too posterior or in the fornix.

* Prevention: Instillation of topical phenylephrine before surgery constricts conjunctival vessels. Light application of bipolar cautery or pressure on oozing site with cot-
ton tipped swab soaked in 1:1000 adrenaline also aids in this regard.

Muscle vessels: Anterior ciliary arteries and veins are cut during most muscle operations during disinsertion, but the bleeding is surprisingly not much. More extensive hemorrhage occurs if a ciliary vessel is cut anterior or posterior to muscle. Cauterization should be performed only if bleeding has not stopped before conjunctival closure.

Inferior oblique muscle is most likely to bleed after myectomy (Fig. 13.4) and the resulting ecchymosis resolves in a few days.

Vortex veins: Vortex veins are close to vertical recti and obliques and hence they must be identified and avoided during muscle surgery.

Fig. 13.4: CT scan showing retrobulbar hemorrhage in left orbit after IO myectomy. (Courtesy: Mark J Greenwald and Janice Lasky)
Scleral Perforation

Penetration of globe by needle during muscle surgery has been reported at a frequency ranging from 1 to 10%. Fine side cutting spatulated needles reduce the incidence of this complication. Fortunately scleral perforation usually does not cause dangerous sequelae. However, the possibility of vitreous hemorrhage, lens dislocation, endophthalmitis and RD makes avoidance of this complication an important concern.

Prevention

- Use of fine spatulated needles (Fig. 13.5).
- Use of hangback technique especially if sclera is very thin.
- Proper passage of needle so that it is visible through overlying scleral layer (Figs 13.6A to D).

Detection of needle perforation is suspected if the needle reaches a depth that precludes visualization of its tip or if there is loss of normal tissue resistance. There

Fig. 13.5: Scleral sections showing safety of spatulated needles. (Courtesy: Eugene Helveston)
may be pigment or vitreous from the needle track. The perforation must be confirmed with indirect ophthalmoscopy with scleral indentation (Fig. 13.7). Frequently, the only fundus abnormality is localized loss of choroidal pigment, that appears as a white lesion.

**Muscle disinsertion:** Scleral penetration can occur when disinserting muscle with scissors (especially in resurgeries with tight muscle).

**Prevention:** Disinsert muscle with small, controlled scissor bites under visualization.

**Treatment:** Large, full thickness scleral breaks should be closed with sutures. If retina is involved – cryopexy or laser should be done with placement of scleral buckle. A partial thickness scleral wound does not require treatment.
Muscle Retraction

Retraction of a detached muscle into the posterior orbit is probably the most feared complication in strabismus surgery.

Types

- ‘Lost’ muscle—muscle is entirely disconnected from globe.
- ‘Slipped’ muscle—muscle is connected through a thin tissue bridge that is believed to represent empty muscle capsule (Figs 13.8 and 13.9).

Fig. 13.7: Needle tract lesion caused by deeply placed suture. (Courtesy: Theodore Krupin, Kolker and Rosenberg)
**Fig. 13.8:** Slipped muscle. (Courtesy: Theodore Krupin, Kolker and Rosenberg)

**Figs 13.9A and B:** Slipped muscle. (Courtesy: Complications in Ophthalmic Surgery by Krupin, Kolker and Rosenberg)
• ‘Pulled-in two’ syndrome (PITS) – in some elderly or debilitated patients, muscle fragmentation may result with muscle traction (Fig. 13.10).

Prevention: Careful attention to suture preplacement before disinsertion particularly when making lockbites. In high-risk situations, anchor a temporary ‘security stitch’ posteriorly in muscle belly. Pay particular attention while operating on medial rectus.

Identification and recovery of retracted muscle: Remain calm and approach intraoperatively retracted muscle
Complications in Squint Surgery

systematically—optimizing illumination, magnification and exposure (Figs 13.11A to D).

Take care to avoid disturbing the fat pad lying approximately 10 mm from limbus between medial orbital wall and muscle.

The inner surface of Tenon’s capsule should be meticulously inspected. Excessive forward traction on Tenon’s should be avoided.

If the muscle is recovered, surgery may then proceed as planned. If recovery is not possible, procedure should

Figs 13.11A to D: Finding a lost muscle. (Courtesy: Theodore Krupin, Kolker and Rosenberg)
be aborted and secondary procedure like transposition of adjacent recti should be done later.

**POSTOPERATIVE COMPLICATIONS**

**Infection**

Infective complications typically present 24 to 72 hours after muscle surgery, but are quite uncommon (overall incidence of less than 1%). These include conjunctivitis, orbital cellulitis and endophthalmitis.

*Prevention:*
- Strict asepsis and sterility protocol
- Topical application of a drop of 5% povidone – iodine during preoperative preparation reduces the conjunctival bacterial load by 90%
- Prophylactic topical and oral antibiotics.

**Immunologic Reactions**

- *Suture granuloma:* Occasionally, an inflammatory, slightly tender lump over the suture may develop within a week or so. It is a foreign body reaction to suture or other foreign matter like cotton fibers (Fig. 13.12).
  
  *Treatment:* Corticosteroid drops are prescribed. If this does not bring resolution, remove the suture and excise the lump (10 days after surgery when the muscle reattaches to sclera).
- Serious inflammatory complications like necrotizing scleritis and fulminant orbitopathy may occur in conditions like active Graves’ ophthalmopathy.
  
  *Prevention:* Do not operate until active ocular signs of inflammation subside and squint is stable for many months.
Anterior Segment Ischemia

It results from inadequate perfusion of iris and ciliary body due to disruption of excessive number of anterior ciliary vessels during surgery.

It is particularly seen when 3 or 4 recti of same eye are operated upon. The condition is rare in children and adults undergoing surgery on only 2 rectus muscles per eye.

Signs and symptoms: Pain, reduced vision, conjunctival injection, corneal edema, DM folds, aqueous flare and cells, generalized or sectoral non-reactivity of pupil, hypotony.

Treatment: Cycloplegics and topical or systemic steroids but the prognosis is guarded.

Prevention:
- Having at least two rectus muscles per eye undisturbed during surgery
- Muscle surgery sparing the anterior ciliary vessels (Mckeown).
Poor Healing

Conjunctiva:

• Prolapse of Tenon’s capsule
  *Prevention:* Careful cleaning and good wound closure.
  *Treatment:* Wait a few days—Tenon’s may shrink inside conjunctiva—if not, it can be excised under local anesthesi.

• Subconjunctival cysts: Entrapment of epithelial cells beneath the surface may cause subconjunctival cysts (Fig. 13.13).

• Adhesive or adherence syndrome: Intense postoperative fibroproliferative response that leads to severe restriction of ocular motility.

*Fig. 13.13:* Subconjunctival cyst (Courtesy: Complications in Ophthalmic Surgery by Krupin, Kolker and Rosenberg)
Complications in Squint Surgery

Corneal Problems

- Epithelial damage – common.
- Dellen formation – if bunching of tissues near the limbus disturbs the tear flow over ocular surface.
- Induced astigmatism.

Change in Eyelid Position

A large unbalanced horizontal muscle surgery may cause slight globe retraction or proptosis with altered palpebral fissure.

  Recession or resection of inferior rectus tends to displace the lid downward or upward due to its firm attachment through Lockwood’s ligament.

Disturbance of Binocular Vision

Postoperative diplopia

Persistence of diplopia beyond two weeks justifies a trial of optical correction like prism. Postoperative diplopia that remains bothersome for two months or longer warrants prescription of permanent prism glasses or further surgery.

Unsatisfactory Alignment

- Undercorrection: Persistence of significant degree of original deviation.
- Overcorrection: Deviation in opposite direction.

At least 10-20% of all operations fail to achieve their goals in terms of ocular alignment, thus necessitating further surgery.
Squint Surgery

Prevention: Thoughtful planning and skilled execution of strabismus surgery may reduce the frequency of postoperative disappointments.

ANESTHETIC COMPLICATIONS

The possibility of anesthesia related complications especially GA must be discussed with patient and/or relatives.

Cardiovascular and Respiratory Complications

- Mortality-risk is very less (< 1 in 1,00,000)
- Oculocardiac reflex – mediated via trigeminal afferent fibers from the orbit and vagal efferent fibers.
  Usually this causes mild transient bradycardia, but rarely it may give rise to more serious arrhythmias like prolonged asystole.
- Malignant hyperthermia: Rise of blood CO₂ level, cardiac arrhythmia and elevation of body temperature.
  Treatment: Dantrolence sodium, 100% oxygen.
- Postanesthetic nausea and vomiting: Quite common after GA.
  Treatment: Antiemetics like ondansetron, emeset.

REFERENCES

SECTION

4

RECENT ADVANCES
WHAT IS NEW IN STRABISMUS?

Stephen P Kraft
INTRODUCTION

In recent years, there have been impressive advances in basic sciences, clinical diagnosis, and treatment in all ophthalmic specialties. The field of strabismus has seen its share of major developments, many of which have changed practice in the assessment and treatment of amblyopia and disorders of binocular vision.

This chapter will discuss many of these advances and how they have shaped the course of the specialty as we complete the first decade of the 21st century. It is not possible to cover all of the new information in this rapidly changing field, but some of the more clinically relevant items will be presented. These advances will be discussed under four main headings:

- Basic sciences and anatomy
- Diagnostic testing
- Medical therapy
- Surgical treatment.

BASIC SCIENCES AND ANATOMY

Infantile Strabismus Syndrome

This common syndrome involves the combination of large angle heterotropia (usually esotropia, rarely exotropia), dissociated vertical deviation (DVD), overaction of the inferior oblique muscles, and latent nystagmus. Another feature recognized in recent years is asymmetry of the smooth pursuit movement of each eye: slow-moving targets generate a much smoother movement when the target passes nasalward before the eye, than do targets moving temporalward. In addition, there are marked fusional vergence deficits as well as congenital deficits of binocular vision processing in the visual cortex.
What is New in Strabismus?

In an effort to understand this combination of anomalies, research efforts have been directed to studies in normal and strabismic infants, and also in a primate model. Data from several laboratories revealed a number of anomalies in the cortex that account for the components of the infantile strabismus complex. The primate model of infantile esotropia has shown loss of horizontal connections between ocular dominance columns in area V1 of the visual cortex, which results in loss of connectivity between the inputs from the two eyes. This decorrelation manifests downstream in maldevelopment of the cerebral pursuit pathways, leading to the nasal-temporal pursuit asymmetry and the impaired disparity vergences. The primate model also shows clinical findings similar to the oblique and dissociated vertical anomalies seen in humans.

An important finding from these studies is that the timing and duration of the insult that upsets the binocular connections is critical. The primate model predicts that, in the human, an insult must occur or exist within the first 2 to 3 months of life to cause the collection of signs seen in infantile strabismus. In addition, the insult must persist untreated beyond the first 6 to 8 months of life. This suggests that realignment of the infant’s eyes should take place very early in life, before 8 or 9 months of age. This is earlier than the longstanding, more typical practice, whereby realignment surgery is usually planned before age 18 to 24 months, with the goal of restoring binocular fusion. As a result, there are ongoing studies evaluating the benefits of “very early” surgery, before age 6 to 9 months, with the goal of not only regaining fusion but also reversing the anomalous eye movement and vergence disorders in this condition (see later discussion under Surgical Treatment).
Squint Surgery

Advances in Orbit Anatomy

In the past 20 years, strabismus surgeons have re-examined the structures and directional paths of the oblique and rectus ocular muscles. Important findings include new understanding of the basic structure of the rectus muscle fibers, and the presence of connective tissue sleeves (“pulleys”) of the six ocular muscles.

Ocular Muscle Structure

The literature until the 1970s divided the ocular muscle fibers into two types, based on the rapidity of response: slow twitch versus fast twitch. The former were characterized by thin motor fibers showing slow sustained contraction, while the latter were thick fibers that contracted quickly and fatigued quickly.5

In the past 20 years, the structural classification of an eye muscle underwent revisions as newer histologic, immunocytoytic, and recording techniques were developed. These studies have led to the dividing of ocular muscle fibers into six subtypes, based on location (global versus orbital), innervation (singly- versus multiply-innervated), and color (red versus pale).6-8 One clinical implication of this reclassification is the finding that botulinum toxin injected into the ocular muscle binds preferentially to the singly-innervated orbital fiber subtype, rather than to any of the other five subtypes.9 A second implication of this new paradigm is the fact that the orbital layers of the ocular rectus muscles, which contain about half of the total number of muscle fibers in the muscles, are the portions that insert via the ocular muscle pulleys (see next section). They are distinct in their mechanical action from the global layers, which contain the other half of the total number of fibers and which insert onto the globe.8
What is New in Strabismus?

Along this theme, a third finding is that there are palisade endings in the global (inner) layer of the extraocular muscles, and these are associated with non-twitch multiply-innervated muscle fibers (MIF). There has been a great deal of research in recent years into the possible role of these endings. One hypothesis states that they are afferent sensory organs providing information about eye position, while the other theory is that they are cholinergic (effector) motor organs. The “palisade ending-MIF motor unit” may be part of a sensory feedback system in eye muscles, which should be considered in association with the causes and treatment of strabismus. Finally, it has been noted that singly-innervated motoneurons are more involved in driving eye movements, and that multiply-innervated motoneurons help to set the tonic tension in eye muscles.

The ocular muscle subtypes have also been characterized by their distribution of myosin heavy chain isoforms. These analyses have shown that the six ocular rotatory muscles are immunocytologically different from the levator palpebrae muscle, which is often included as one of the extraocular muscles, as well as from extraocular muscles in other species.

Ocular Muscle Pulleys

A second major advance in eye muscle anatomy is the characterizing of the connective tissue sleeves, or “pulleys”, of the ocular rectus and oblique muscles. These pulleys are located within Tenon’s fascia, just posterior to the equator of the globe. The structure of these pulleys includes soft tissue, elastin, and richly innervated smooth muscle. As noted earlier, the fibers of the orbital layer terminate on the sleeve while the global layer passes through the pulley and inserts onto the globe. As a result of this dichotomy
of anatomic insertions of the two portions of the muscle, the global layer mainly rotates the globe whereas the orbital layer translates the pulley to control the direction of globe rotation. Pulleys have been described for the oblique muscles as well as the rectus muscles.\(^\text{13}\)

This new anatomic paradigm has led to revised thinking of the etiology of several common strabismus entities, as well as rethinking of the approach to surgical treatment of these and other conditions. A good example is the etiology of the A and V syndromes, which have been ascribed primarily to oblique muscle dysfunction for many years. However, detailed radiologic studies, in concert with orbit dissections, have shown that some of the A and V syndromes are, in fact, caused by anomalous positions of the pulleys within the orbit. Thus, repositioning of the pulleys has been designed as a more physiologic and effective approach in some cases, rather than surgery on the oblique muscles. A second surgical application is a new variation on the posterior fixation suture (“fadenoperation”), whereby suturing of the rectus muscle to the pulley may be as effective as tacking down the rectus muscle to the sclera.\(^\text{12}\) Finally, radiologic analysis of transposition surgery for paralytic strabismus has shown that the benefit of this surgery in realigning the eye and improving ductions is related to a marked lateral displacement of the pulleys of the transposed muscles.\(^\text{14}\)

**Computer Modeling of Strabismus**

The exponential increase in computer capacity has allowed development of software that can model the orbital and ocular motor “plant”. The updated versions of these programs incorporate recent advances in orbit and extraocular muscle anatomy, biochemistry, physiology, and
biomechanics to simulate both simple and complex eye movements. They also allow surgeons to predict the effect of a small or large perturbation on the normal eye movement plant, in terms of both clinical effects and possible surgical implications.

**Genetic Basis of Strabismus**

In recent decades, there have been ongoing studies on the heritability of strabismus, including the common forms of exotropia and esotropia as well as complex forms such as Duane syndrome, Brown syndrome, congenital fibrosis of the extraocular muscles (CFEOM), and congenital fourth nerve palsy.17 The pathogenesis of comitant strabismus, in the absence of structural abnormalities of the eye or brain, is currently considered to be inherited as a complex genetic trait, with contributions from both genes and the environment.18 Recent work has suggested that there are multiple loci for comitant strabismus.19

Several congenital forms of incomitant strabismus present with nonprogressive restrictive strabismus. These include CFEOM and Duane syndrome, which until a few years ago were considered anatomically and physiologically distinct entities. However, anatomic and neurophysiologic studies have challenged this thinking, and these entities are now considered part of a spectrum of congenital disorders of innervation. Several other disorders have now been grouped with these two entities, including Möbius syndrome, familial horizontal gaze palsies, and congenital third and fourth nerve palsies.18,20 These seemingly disparate clinical syndromes all arise out of mutations in genes critical to the development of ocular motor neurons and their connections.20 Thus in 2003, the term "congenital cranial disinnervation disorders (CCDDs)" came into
existence to apply to this group of strabismus entities. Several genetic loci have been identified for most of these syndromes.

**DIAGNOSTIC TESTING**

**Assessment of Infant Vision**

In the 1970s, initiatives arose to develop tools to assess vision in children who were too young to perform conventional vision tests including Snellen or Allen pictures. These studies proceeded along two related but parallel paths, one involving creation of manual tests for use in the clinical setting, and other utilizing visual technology and computer generated images.

It is now possible to determine quantitative vision levels in infants as young as a few months old using clinical tests based on grating acuity cards, which include Teller acuity cards and Cardiff cards. These tests are widely used by orthoptists and ophthalmic assistants to diagnose vision disorders in preverbal or nonverbal children, and to guide treatment for amblyopia and refractive errors, among many other ophthalmic conditions. However, there have been concerns raised about the specificity and sensitivity of these tests in detecting amblyopia, when compared to optotype tests. Computerized tests, such as the pattern-onset and the sweep visual evoked potential (VEP), allow quantitative vision assessments in the laboratory setting, both for diagnostic and research purposes. In addition, more accurate recognition tests for slightly older children are now in common use, including LEA symbols and single optotype cards with interaction bars, which address the issue of the crowding phenomenon in amblyopia.
Photoscreening

Large-scale vision screening of children has been an active area of research in recent years. Instruments have been developed that can detect various ocular disorders, and which are easy to use for both experienced and lay practitioners. At the same time, many devices provide accurate data with high sensitivity and specificity. Among the most useful ones invented for these purposes are photoscreeners, which have the ability to detect misalignment of the eyes, refractive errors, and media opacities.

There have been several prototypes produced in recent years. The most widely-evaluated one is the MTI Photoscreener (MTI, Cedar Falls, Iowa, USA), which can be worked by a lay individual, while photos are analyzed by experienced observers. Successful programs using this device have been undertaken in the United States.29 Other photoscreening instruments have been validated in other studies, each with its own advantages. In addition, autorefractors have been found to be valid as screening tools for detecting significant (and amblyogenic) refractive errors in large population-based studies.29

Plotting the Field of Binocular Single Vision

There are several means of recording data of eye muscle balance, with most schemes involving static measurements of alignment in different fields of gaze. While such data are helpful in following strabismus cases and planning surgical dosages for surgery, strabismus specialists have recognized that static data do not always reflect the dynamic situation when the eyes are tracking targets. To address this gap, many investigators have developed alternative recording methods, including the field of binocular single
vision (BSV). This test documents the fusion field of the patient as the eyes are moved into specified directions away from the primary position.

The test is usually performed with a Goldmann or arc perimeter in order to capture the entire binocular field. The target used in a Goldmann apparatus is often a spot, but fusion targets have been incorporated into the testing devices to enable detection of torsional as well as horizontal and vertical disparities. Within the last five years, an alternative test using a cervical range of motion (CROM) method has also been introduced, and this procedure can be used if a Goldmann perimeter is not available. In both cases, a weighted scoring template is also available to provide a BSV score for a plot.

Weighted scoring methods of the field of BSV have several uses:

1. They can allow the surgeon or orthoptist to follow a patient’s eye muscle problem serially over time.
2. They provide a preoperative picture of the strabismus problem and the areas of the field where fusion is lacking.
3. The score can be used in prospective or retrospective studies to compare different surgical methods for a specific entity.
4. The scores can be used to compare the results of the same surgery done by different surgeons.
5. The weighted score can be used as a quantitative measure of disability in medical-legal and insurance claims.

**Eye Movement Recording**

For several decades, investigators have used eye movement recordings to document abnormalities of the various eye movement systems, including saccades, smooth pursuit,
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Vergences, and optokinetic anomalies. In recent years, these devices have become increasingly sophisticated and precise in providing dynamic eye movement data to diagnose and follow strabismus and neuro-ophthalmologic eye movement disorders. Systems incorporating search coils or infrared detection devices have allowed tracking of eye movements in three dimensions.32,33 Eye movement recordings have proven invaluable in assessment of nystagmus, ocular motor nerve pareses, dissociated vertical deviation, myasthenia, external ophthalmoplegia, and restrictive strabismus.

Studies using eye movement recordings have led to reclassifications for many disorders. One example is the abandoning of a long-held separation of “motor” versus “sensory” nystagmus to describe nystagmus waveforms resulting from, respectively, primarily efferent and primarily afferent ocular diseases. Modern eye movement recordings have shown that infantile nystagmus waveforms are complex, and cannot separate out those patients who have a congenital eye disorder from those who do not have one. This has led to a new terminology, with the older term “congenital nystagmus” being replaced by “infantile nystagmus syndrome (INS)”. Another new term is “fusion maldevelopment nystagmus syndrome (FMNS)” to replace the long-held term “latent/manifest latent nystagmus”.36 The quantitation of recordings has also led to new indices of fixation quality to measure visual performance and predict improvements after eye muscle surgery for nystagmus.

The “Four-Step Test”

There has been a steady increase in knowledge of the supranuclear pathways that control eye movements, including the pathways in the brainstem and cerebellum and their
connections to the utricles and saccules of the inner ear. These pathways affect the eye muscles in several ways, one of which is the control of ocular counterrolling and vertical eye movements.

In light of these gains in knowledge, a fourth step has recently been added to the traditional “3-step test” that has been in use for many decades in order to diagnose a 4th nerve paresis. This clinical test involves, firstly, the labelling of the hypertropic eye in primary position. In the second step, one records the lateral gaze in which the vertical tropia worsens, and this step isolates the possible paretic muscle to either the superior oblique of the hypertropic eye or the superior rectus of the fellow eye. The third step is the forced head tilt test (or Bielschowsky head tilt test) to the right and left shoulders, and this step isolates the offending muscle by determining on which tilt the hypertropia worsens.37

However, one entity that can mimic some features of a superior oblique paresis, especially an incomitant hypertropia or hypotropia, is a skew deviation, which is a vertical strabismus caused by lesions in the brainstem tegmentum or cerebellum, or due to peripheral vestibulopathy.38 In order to rule out a skew deviation, a new paradigm involves a fourth maneuver: measuring the vertical heterotropia and cyclotorsion in the sitting position, and again in the reclining position. Whereas a 4th nerve paresis will show no change in the vertical deviation and subjective excyclotorsion in the sitting and reclining positions, a skew deviation will show marked reduction or elimination of the vertical deviation and torsion when the patient reclines.38
Radiologic Advances

Ultrasound Biomicroscopy

Ultrasound biomicroscopy (UBM), involving the use of high frequency output (50 MHz), was developed in the 1980s for diagnosis of anterior segment conditions such as glaucoma and iris tumors. In the last 10 years it has proven to be a valuable tool for detecting the insertions of the four ocular rectus muscles, both in patients undergoing primary strabismus surgery and in those undergoing reoperations. The probes used in this test can detect muscle insertions as far posteriorly as 14 mm from the limbus for the lateral rectus and 12 mm for the medial rectus and vertical rectus muscles. The UBM can also differentiate a connective tissue “pseudotendon” from the true muscle insertion.

Computerized Tomography (CT) and Magnetic Resonance Imaging (MRI)

Improvements in technology have made these two modalities increasingly sensitive to subtle lesions and anomalies that can lead to strabismus problems. The field of CT scanning has undergone major changes in recent years with the introduction of helical or spiral scanning to the conventional imaging programs. This modality is still the preferred study for orbit bony problems, especially to visualize fractures after trauma. Newer scanners can also produce impressive 3-dimensional views of the orbits and cranial vault, and this technology has revolutionized treatment for craniofacial and orbit disorders, many of which can affect the eye muscles.
In recent years, MRI scanning has also undergone major advances, including a steady reduction in time intervals needed to complete a study. This factor has been particularly beneficial in the context of pediatric cases. Newer scanners give unprecedented details of the soft tissues, allowing assessment of a wide range of eye muscle disorders. This technology has been used by researchers to model the extraocular muscles and to redefine the anatomy of the orbital soft tissues. One example is the characterization of the ocular muscle pulleys and their effects on eye muscle alignment and dynamic eye movements (as described earlier).12

Dynamic MRI, or the imaging of the eyes in real time during guided eye movements, has proven instructive in diagnosing various eye muscle conditions. Following the traumatic severing of an eye muscle, dynamic MRI can be used to assess the integrity of a residual portion of muscle. It is also useful to view the co-contraction of eye muscles in misinnervation syndromes such as Duane retraction syndrome.42,43

**Other Imaging Advances**

Other modalities have been applied in assessing eye muscle problems. Positron emission tomography (PET) detects biochemical changes in body tissues. It has been useful in detecting lesions that may be missed by MRI or CT scan, such as brainstem disorders that affect the eye muscles.44 Advances in optical coherence tomography (OCT) have led to accurate depiction of the anterior segment of the eye, in addition to its value in imaging the posterior segment structures.45 It can yield detailed views of the cornea, chamber angle, and sclera, which may some day allow accurate visualization of the extraocular muscle insertions, now possible only with the ultrasound
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biomicroscope. Finally, a new high-resolution X-ray-based imaging technique known as diffraction-enhanced imaging (DEI) gives very high-resolution images of the eye, and it may in the future provide an alternative method of detecting eye muscle position.46

Telemedicine

Telemedicine is a method for transmitting images and data over long distances for diagnostic and treatment purposes. It is being used in ophthalmology at an increasing rate in the diagnosis of such disorders as retinopathy of prematurity and retinal diseases. It has also been shown to be useful in assessing strabismus cases, whereby static images of a strabismus case can be sent to another city on the same or a different continent for analysis.47

With advances in video technology, the analysis of strabismus cases can now be done via telehealth setups that allow dynamic video recordings. The examination can be done on a delayed telecast basis, or in real time as the patient is examined by the ophthalmologist or orthoptist at the site of origin. The first study on the accuracy of real-time video to diagnose strabismus cases was carried out in Canada in 1999, with transmission over 1500 km between Toronto, Ontario and Thunder Bay, Ontario. With the bandwidths available at that time, the study showed that horizontal deviations were more accurately measured than vertical deviations.48 It is expected that the marked improvements in technology would allow much higher accuracy in agreement between observers at the site of the examination and the remote site.
Botulinum Toxin

Botulinum toxin injections were introduced in 1978 as an alternative to strabismus surgery. Injections of the toxin were also found to be useful in controlling facial muscle spasms in various forms of dystonia and in hemifacial spasm. Its range of uses increased rapidly over the ensuing years such that, currently, there are several dozen uses for this drug both in the medical and cosmetic spheres. The main drawback to using this agent is its temporary effect. However, thirty years of experience with botulinum toxin in strabismus has shown that it has a role to play in various eye muscle disorders.49

Botulinum toxin has been used to treat various conditions in adults, especially sensory strabismus and acute ocular muscle palsies. Several years ago, it was touted as improving the recovery rate after acute sixth nerve palsies if it was injected into the medial rectus within a few weeks of onset of the palsy. This expectation has not been supported by recent studies on traumatic palsies.50 However, the injection can temporarily reduce a compensatory head posture and preserve binocularity until definitive treatment is undertaken.51

Although some practitioners use botulinum toxin for a wide variety of strabismus conditions, it has proven especially effective in certain contexts.51,52 It has a high rate of success for small angle strabismus, usually less than 20 prism diopters, and for postoperative undercorrections or overcorrections associated with diplopia.49,51 It is used as an adjunct for transposition surgery for sixth or third nerve palsies.51 It has also been effective in reducing symptoms of oscillopsia due to acquired nystagmus.55 Botulinum injections can be helpful when surgery is risky, such as cases
of pre-phthisical eyes or in eyes in which glaucoma or retinal surgery can increase the risk of anterior segment ischemia after surgery.

Botulinum toxin has proven effective in treating comitant strabismus in children. Some authors have achieved success in treating infantile strabismus that matches surgical success rates, both in terms of motor and sensory outcomes.54,55 These authors injected muscles in both eyes at the initial treatment. Experience in children, as in adults, has shown that the rates of satisfactory alignment after injection of one eye muscle are higher for small angles of strabismus, usually under 20 prism diopters.49

**Injections of Local Anesthetic**

Observations of eye muscle conditions resulting from unintended intramuscular injections of local anesthetic for cataract and retinal surgery have led to the notion that intentional injection of a rectus muscle could realign an eye. This has been borne out by pilot studies involving the injection of bupivicaine, a long-acting local anesthetic, into the lateral rectus muscles of patients who had undercorrected strabismus after prior esotropia surgery.56 Further experience in larger studies, and in a variety of conditions, will be required before it becomes an accepted alternative to surgery.

**Treatment of Amblyopia**

**Traditional Methods**

There have been numerous prospective controlled randomized studies carried out in the last 10 years that have confirmed some long-held concepts and also yielded a
great deal of new information on the treatment of amblyopia. Many of these studies were carried out by a large group of pediatric eye specialists in North America known collectively as the Pediatric Eye Disease Investigator Group (PEDIG).

The following is a list of some of the important conclusions that have been learned thus far from these and other related studies:57-60

- For children age 3 to 7 years with unilateral amblyopia and vision at least 6/30 (moderate amblyopia) and who had no prior therapy for amblyopia, daily atropine penalization leads to the same rate of improvement in vision over a 6-month period as 6 hours per day of patching.
- For the same age group with the same range of starting visions, patching of 2 hours per day generates the same rate of improvement as 6 hours per day over a 4-month period.
- Also in this age group with moderate amblyopia, atropine drops given only on the weekend leads to the same rate of improvement as daily atropine administration.
- In the same age group but with vision poorer than 6/30 (severe amblyopia), patching 6 hours per day yields the same rate of improvement as full days of patching over 4 months of follow-up.
- In treating anisometropic amblyopia, spectacle correction alone can lead to an improvement in vision over a 2-month period of follow-up. This improvement is also possible even if there is strabismus present with glasses. If the vision reaches a plateau with spectacles alone, adding patching for 2 hours per day can yield a further increase in vision over a 2-month interval.
- Among patients between 7 and 12 years of age with moderate or severe amblyopia, up to one-half will gain
more than 2 lines' improvement in vision using either patching, or patching accompanied by penalization over a 6-month period of follow-up.

- Among patients between 13 and 17 years of age with moderate or severe amblyopia, patching or patching plus penalization can yield an overall improvement in vision of at least 2 lines in one quarter of individuals. The success rate is higher than this (at almost 50%) among the sub-group of patients who have not had prior amblyopia therapy.

- Among patients whose vision improved at least 3 lines with patching, abrupt cessation of patching will result in a slipping of vision over the ensuing few months. Thus, after ceasing daily patching, the hours should be tapered over a few months to be sure the vision does not slip.

- Correction of refractive error alone can lead to improved vision in a majority of patients with previously untreated strabismic amblyopia.

- The diligent use of near work for the amblyopic eye during the treatment period does not improve the results of therapy.

- The improvement in vision seen with atropine penalization is not contingent on inducing a switch in fixation preference during the cycloplegia.

- Spectacles as the sole intervention for bilateral ametropic amblyopia can improve vision over a period of up to 12 months.

  Other studies in recent years have also clarified some issues in the treatment of amblyopia, including the following information:\textsuperscript{61,62}
  
  - Once the maximum vision is reached with patching therapy, if no improvement is seen with continuation of treatment for three subsequent age-adjusted
intervals (each up to 4 weeks maximum), then the therapy should be tapered.

- Long-term follow-up of patients who had patching treatment for amblyopia in childhood showed that the vision improvement was maintained into adulthood in at least two thirds of cases.

It should be evident from these many lines of evidence that the chance of reversing amblyopia is no longer limited only to children under the age of visual maturity (age 8 or 9 years). Current practice requires the practitioner to consider offering treatment to patients of any age if they have not previously had an adequate trial of accepted therapy. While no guarantee can be given as to efficacy of therapy, it is not possible to predict which older child or teenager may respond. Thus, the mantra in the older age groups is to “never say never”, but to discuss the option of therapy with any patient who wishes to improve his or her vision.

**Newer Alternative Approaches**

There are oral medications that have shown efficacy in improving vision in amblyopic patients, usually in conjunction with patching. Dopaminergic analogs, usually L-Dopa with Carbidopa, have led to greater improvements in vision than patching alone. Most of the improvements in vision were evident within 6 weeks after initiation of treatment. In some cases the vision tended to regress slightly after the oral medication was discontinued, but it did not revert back to the original vision level. Another medication, citicholine (or CDP-choline), is available in Europe and has been shown to stabilize the improved vision in conjunction with patching treatment for amblyopia.
In recent years, there has been a large and growing interest in the plasticity of the human brain and production of agents or interventions that can prolong or actually restore brain plasticity, especially in adults. Recent research has shown that the critical period in animals can be revived or prolonged with the use of drugs that alter biochemical signals in the visual pathway, such as Prozac, Valium, GABA-minergic compounds, and proteins such as Nogo and Otx2. In addition, repetitive transcranial magnetic stimulation (rTMS) has shown promise in improving contrast sensitivity in amblyopic eyes, indicating plasticity in the amblyopic visual cortex. These interventions may hold promise for the future in improving the success rates and rapidity of response in amblyopia, and also potentially to prolong the age range within which vision deficits can be reversed.

SURGICAL TREATMENT

Refractive Surgery

There are two groups of patients for whom refractive surgery has become a fertile ground for research and treatment: adults with refractive-based strabismus, and children with amblyopia who are not responsive to or who are not candidates for traditional medical therapies.

Adult Refractive Strabismus

Refractive surgery can be a useful alternative in treating some forms of strabismus. There are small case series in adults that have documented the successful treatment of accommodative esotropia by eliminating the hyperopic refractive error. Refractive surgery can also eliminate
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the accommodative component of a mixed accommodative and non-accommodative form of esotropia. It has been reported to eliminate exotropia in two patients with myopic anisometropia when the refractive errors were corrected in both eyes. Small vertical deviations have responded to correction of refractive errors with laser.

On the other hand, refractive surgery can lead to unexpected or unwanted results. In one report, a minority of patients with longstanding accommodative esotropia had no change in their esotropia despite successful correction of the hyperopia. These patients could not be identified by sensorimotor testing prior to the laser surgery. Another article presented a series of myopic patients whose exodeviations worsened significantly after refractive surgery for their myopic errors.

Refractive Surgery in Children

In recent years it has become evident that some children do not benefit from traditional amblyopia therapy, whether it be spectacles for bilateral significant ametropia or anisometropia, or patching or penalization for unilateral amblyopia. Thus, investigators in several countries have turned to laser refractive surgery on a limited number of children. Because of increasing experience with refractive surgery in young children, the role of this treatment is being better defined. In addition, the choice of procedures (LASIK, PRK, or LASEK) that are most effective and safest in specific disorders is also becoming clearer.

In current practice, refractive surgery is considered an option for the treatment of bilateral high ametropia and severe anisometropia when traditional therapy is not tolerated. This approach can be very helpful for children with neurobehavioral disorders. Vision improvements have been impressive in some of the patients studied, and
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A new avenue of research has been in the area of clear lens extraction and refractive lens exchanges for some children with high refractive errors, as an alternative to laser surgery. So far, most of the experience has been in children with neurobehavioral disorders, with these children showing a high rate of success in terms of improved visual behavior and overall demeanor. Finally, the use of phakic intraocular lenses in severe anisometropia has been reported by several surgeons, most of whom practise in European centres. Thus far, these small series have shown significant vision recovery in the majority of patients.

Timing of Surgery in Infantile Strabismus

Recent neuroanatomic and neurophysiologic findings that are elucidating the pathology of the infantile strabismus complex were presented earlier. This new knowledge has led to small pilot studies on “very early” surgery for infantile strabismus, specifically esotropia. Primary surgery has been performed on infants less than 6 months old to try to reverse the vergence and binocular deficits associated with this syndrome. Early evidence suggests that the window for restoring some of the defective processing is within the first few months of life. This work has spawned new prospective studies to try to determine definitively whether “very early” surgery has significantly better outcomes in terms of binocular vision and motor vergences than traditional “early” surgery that is performed in the 9 to 18 month postnatal time frame. The early evidence suggests that surgery for infantile strabismus can be performed up to 10 months of age to accomplish these objectives.
Eye Muscle Surgery

In recent years, strabismus surgery has enjoyed significant progress both in technical quality and variety of procedures available. There are very few strabismus conditions that are currently untreatable, considering the myriad tools available to the surgeon. One paradigm that has shifted in recent years is the design of the strabismus procedure, which is now individualized for each patient. It is no longer acceptable to simply plan correction for the primary position alignment. Planning for strabismus surgery should attempt to maximize the field of BSV (the field of fusion) so that the patient gains the widest possible range whereby the eyes move in tandem. Ideally, single vision should be gained within a range of 30° from the primary position. This may require shifting of the traditional planning of surgery in terms of the choice of muscles and the dosage of surgery.

It is not possible to describe all of the advances in strabismus surgery that have arisen in the last few years. Instead, some of the more important recent approaches and techniques will be discussed.

Surgery for Paralytic Strabismus

It has been known for many years that surgery for a complete third or sixth cranial nerve palsy is not successful in the long-term with a traditional recess-and-resect procedure on the horizontal rectus muscles, even if supramaximal surgery is done. In these cases, the resected muscle does not function, and it cannot prevent the antagonist muscle from “unwinding” the tightening effect of the resection over time. In order to increase the chance of success, several innovative approaches have been devised.
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For a total sixth nerve palsy, transposition surgery has been done on a wide scale for many years. The most common approach has been a total vertical rectus muscle transposition to the lateral rectus insertion, or some form of muscle tethering such as the Jensen procedure in which halves of the lateral rectus are tethered to the respective lateral halves of the vertical rectus muscles. In both procedures, the medial rectus has to be weakened as part of the plan, either in the form of a recession, or by means of a botulinum injection.\textsuperscript{85} However, in the past 10 years a variation of the full muscle transposition has been used successfully in many cases. This option involves retroequatorial myopexy sutures to redirect the vertical muscles into a horizontal configuration above and below the lateral rectus. This variation, also known as the Foster modification, has the advantage of not requiring concurrent weakening of the medial rectus: a recession or botulinum injection of the muscle is needed only for unexpected undercorrections after the primary transposition.\textsuperscript{85,86}

For complete third nerve palsy, a novel approach involves completely detaching the antagonist lateral rectus and fixing it to the periosteum of the lateral orbital wall.\textsuperscript{87} The medial rectus is supramaximally resected at the same time, but the fact the lateral rectus is off the globe reduces the chance of recurrence of the exotropia with time. In the past, an alternative approach was the large recess-and-resect procedure with nasal and medial transposition of the superior oblique tendon to just above the medial rectus insertion. This is still performed in some centers, but seems to have fallen out of favor among a majority of eye muscle surgeons.
Surgery for Incomitant Strabismus

One of the current strategies in treating incomitant eye muscle deviations is the balancing of rotations of yoke muscles to restore comitance of eye movements. The goal is to expand the field of binocular single vision (BSV) into the field where diplopia or visual confusion is present. The yoke muscle surgery is done on the fellow eye. This strategy is used in many scenarios:

- For a paresis of a lateral rectus or mechanical restriction of abduction, one weakens the medial rectus of the contralateral eye.
- For a paresis of a medial rectus or an adduction restriction, one weakens the lateral rectus of the contralateral eye.
- For a downgaze paresis or a restriction to downgaze, one weakens the inferior rectus of the fellow eye.

For many years the most common method of achieving this comitance was to perform a retroequatorial posterior fixation suture ("fadenoperation") on the yoke muscle of a weak agonist. In recent years, two different surgical options were introduced as alternatives to the fadenoperation. One approach involves a combination of a recession and resection of the (same) yoke muscle. In the most current version of this procedure, the recession is made 2 or 3 mm larger than the resection. The advantage of this option is the opportunity to use an adjustable suture on the muscle in order to titrate the degree ofduction limitation to match that of the limited yoke muscle.

Another variation of the fadenoperation is derived from the anatomic studies of the rectus ocular muscle pulleys described earlier. Rather than place intrascleral sutures retroequatorially on the muscle, the surgeon can fix the rectus muscle belly directly to the pulley. This procedure has been performed only on a limited number of subjects,
so long-term experience is still lacking. However, it can also be used in cases other than incomitant deviations, such as convergence excess esotropia in children, whereby a surgeon wishes to create a medial rectus posterior fixation effect.

**Misplaced Ocular Muscle Pulleys: A and V Syndromes and High Myopia Strabismus Fixus**

As noted earlier, characterization of the rectus ocular muscle pulleys has opened new surgical paradigms for treating strabismus entities. One example already discussed is the understanding of the anatomic causes of the A and V patterns, which are commonly seen in strabismus practice. While most cases in the past were ascribed to oblique muscle anomalies, it has been well documented that a significant minority of these patterns are, in fact, caused by anomalous rectus muscle pulley positions. For example, an A-pattern can be caused by superior oblique overactions, but it may also be due to superiorly malpositioned lateral rectus pulleys. The correct surgical option in the latter scenario would be a realigning of the lateral rectus pulleys by infraplacing the muscles, rather than utilizing a superior oblique weakening procedure. The opposite argument applies to a V-pattern exotropia.

One entity whose pathophysiology and surgical management has been clearly redefined by the knowledge of the pulley system is the case of a very highly myopic globe with large esotropia and hypotropia. Scanning of these orbits with MRI or CT shows a significant derangement of the rectus muscle pulleys, such that the superior rectus and inferior rectus are misplaced well medial to their normal positions, while the lateral rectus is redirected inferiorly and medially to where it is normally situated. A recess-and-resect of the horizontal rectus muscles worsens the
abnormal physiology by driving the eye more inferiorly while not adequately dealing with the esotropia. Instead, a reanalysis of the orbit scans in these patients led to a solution involving closing the large superior-lateral gap that exists between the lateral and superior rectus muscle pulleys. A simple tethering of these two muscles with a nonabsorbable suture near the equator restores the more normal pulley positions and repositions the eye properly in the primary position.94

**Inferior Oblique Muscle Surgery**

The past 20 years have witnessed the introduction of various innovative procedures on the inferior oblique muscle. One variation is the anterior transposition of the inferior oblique (ATIO) in which the muscle insertion is transposed to just lateral to the lateral pole of the inferior rectus insertion. This redirection of the muscle renders it an anti-elevator of the globe. The ATIO has become very popular as an alternative to superior rectus recession or superior rectus posterior fixation suture for dissociated vertical deviations (DVD).95,96 Although it is generally performed when the inferior oblique muscle is also overacting in addition to the presence of DVD, it can be effective as a procedure on its own when only DVD is present.95 This surgery is also used in treating superior oblique paresis when the inferior oblique is significantly overacting, and it is used as well in conjunction with superior rectus recession to treat a chin-down head posture due to infantile nystagmus syndrome.97

More recently, other procedures on the inferior oblique have been described. One variation with which surgeons have had limited experience thus far is transposition of the inferior oblique to the nasal side of the inferior rectus insertion. This option creates a downward vector to the
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inferior oblique, to aid in treating complex downgaze problems.98

**Superior Oblique Muscle Surgery**

In parallel with developments in inferior oblique surgery, new options for dealing with the superior oblique tendon have also been introduced. One popular innovation in recent years is the weakening of the superior oblique on the nasal side of the superior rectus by inserting an artificial device between the tenotomized ends of the tendon. The two options for insertion are a retinal band (band spacer) or a nonabsorbable suture (suture spacer).99,100 These advances have proven effective for treating Brown syndrome and primary overactions of the superior oblique muscle causing A-patterns.

Another effective surgery that has been performed for many years is transposition of the anterior fibers of the superior oblique tendon to the lateral rectus, to treat exyclodiplopia. The two most popular variations of this procedure are the Harada-Ito procedure, in which the anterior fibers of the tendon are displaced toward the lateral rectus without detaching them from the insertion, and the Fells modification in which the anterior half of the tendon is detached from its insertion and moved to the upper border of the lateral rectus. The surgery was also described with the addition of adjustable sutures.101 However, experience has shown that the surgery is highly predictable in resolving exyclotropia such that adjustable sutures are not required in most cases.

**Surgery for Duane Syndrome**

One of the impressive advances in surgical treatment is the proliferation of approaches to dealing with this complex strabismus syndrome. One of the fundamental changes has
been the recognition that Duane syndrome is a spectrum of innervational anomalies, with the common feature of globe retraction on adduction due to co-innervation of the lateral and medial rectus on attempted adduction. Several lines of evidence have elucidated the underlying mechanism of this spectrum of eye muscle disorders, including neuroanatomic studies showing hypoplasia of the sixth nerve and its nucleus, with miswiring of the third nerve to the lateral rectus.

Electromyographic and dynamic MRI studies (discussed earlier) have consistently demonstrated that the lateral rectus is anomalously innervated when the eye tries to adduct. In addition, there has been progress on the genetic front, with new genetic loci found in association with some familial cases of Duane syndrome. Recent work, also discussed in a previous section, has put this series of disorders under the banner of the congenital cranial disinnervation disorders (CCDDs), which includes congenital fibrosis of the extraocular muscles (CFEOM), Möbius syndrome, congenital 4th nerve palsy, and congenital 3rd nerve palsy. Embryologic and epidemiological work have also suggested that the in utero timing of development of the misinnervation in Duane syndrome occurs within a narrow time frame, between 6 and 8 weeks of gestation.

As a result of these many lines of research and observations that confirm the variability of the signs of this spectrum of disorders, it is no longer acceptable to classify Duane syndrome into 3 or 4 clinical types based solely on its clinical presentation. Instead, it is more effective to analyze a given case according to five clinical features:

- Presence of a compensatory head posture
- The type of heterotropia in primary position, if the eyes are not straight
- The severity of retraction on adduction
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- The presence of upshoots and/or downshoots on adduction of the eye, and whether they are due to innervational or mechanical factors, or both
- Whether the syndrome is unilateral or bilateral.

In recent years, several innovative surgical approaches have been developed to deal with the many clinical abnormalities in the various forms of Duane syndrome, including: severely limited abduction in esotropic Duane syndrome, upshoots and downshoots in exotropic Duane syndrome, and severe retraction. Some of the newer procedures involve transposition of the vertical rectus muscles, with or without deactivation of the lateral rectus. Surgery on the fellow eye in unilateral cases is sometimes necessary to optimize a result. Rarely, a small resection of a lateral rectus can be used to treat some forms of Duane syndrome with esotropia.

Adjustable Suture Surgery

Since the 1960s, adjustable sutures have become commonplace as an adjunct to eye muscle surgery in adults. The two basic methods include a bow-tie knot or a suture handle slip knot. There have been many novel methods developed over the years to optimize the ease and success of this useful addition to strabismus surgery. Some of these advances include methods allowing suture adjustment many days after the original surgery. Other approaches involve suturing the muscles such that if the alignment is satisfactory after surgery, then no manipulation of the sutures is needed, and they can be left in situ.

One of the developments in recent years has been the addition of adjustable sutures for surgery in children. This method is practiced by many strabismus surgeons worldwide. It usually requires leaving the sutures buried under the conjunctiva at the end of surgery. Then the surgeon
and anesthetist have to make time to assess the child’s eye alignment in the recovery room later on the day of surgery when he or she is wide awake. If the result is satisfactory, the sutures are left alone. If the result is not optimal, then the child is given a short-acting anesthetic, such as nitrous oxide, so that one attempt can be made to correct the residual angle.

**Ciliary Vessel-Sparing Surgery**

A major advance in strabismus surgery was the development of effective means to perform rectus muscle repairs without disturbing the ciliary artery supply to the muscle. This approach is used in situations where there is a risk of anterior segment ischemia:

- The patient has had multiple prior eye muscle repairs on various muscles.
- There are serious systemic vascular issues.
- More than two rectus muscles have to be detached during the same surgery on one eye.
- The eye is at a risk of phthisis due to prior intraocular surgeries.

The vessel-sparing procedure is a very meticulous and lengthy surgery requiring a long learning curve for the strabismus surgeon. It is performed using an operating microscope and specialized microsurgical instruments. When done by experienced surgeons, it can be a valuable adjunct to the strabismus surgery arsenal.

**Nystagmus Surgery**

Recent years have seen a great deal of interest in and new approaches to the diagnosis and treatment of nystagmus in children and adults. Some of the newer terminology and phenomenology has been discussed earlier. There are
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newly revised algorithms for determining the type and nature of a given case of nystagmus. By appropriately characterizing the form of nystagmus, a reasonable surgical approach can be devised.

The most common reason for surgery in a case of infantile nystagmus syndrome (formerly known as "congenital motor nystagmus") is a compensatory head posture due to an eccentric null zone. There are now approaches to dealing with all possible orientations of head postures, including combinations of face turns, chin-up or down postures, and head tilts. Many cases require surgery on up to four muscles, often in both eyes. If there is an associated strabismus, then the surgery on the extraocular muscles can be adjusted to take this factor into account.

If there is no strabismus and no compensatory head posture, then surgery can be done to improve vision by reducing the intensity of the nystagmus. One approach is artificial divergence surgery involving large medial rectus recessions, if convergence dampening can be demonstrated using a trial of prisms. A newly described alternative method is bilateral tenotomy of the four rectus muscles with reattachment at the original insertions. This option takes advantage of new concepts about the presence of proprioceptive afferents in the muscle tendons that are involved in feedback to the ocular muscles. A less popular but still widely practiced variation is supramaximal recessions of all four horizontal rectus muscles. Finally, if there is strabismus present along with nystagmus, a new approach is to perform two-muscle surgery to correct the misalignment and to add a tenotomy and reattachment of the remaining two rectus muscles. Further long-term studies in multiple centers will be needed to determine the efficacy and advantages of these newer approaches.
A discussion of advances in strabismus surgery would not be complete without addressing the functional benefits of adult strabismus surgery. In recent years, there has been a growing body of evidence substantiating the many advantages of correcting eye misalignments in patients beyond the age of visual maturity. These studies counter a commonly held belief that adult strabismus correction is purely “cosmetic”. In fact, strabismus is an abnormal motor and sensory state, and any realignment is actually “restorative” or “reconstructive” surgery.

The benefits can be summarized under six categories:

- **Elimination of symptoms**: Eye muscle surgery in adults can eliminate diplopia and asthenopia in a majority of cases. Torticollis due to strabismus can also be reduced or eliminated in most cases.

- **Regaining of binocular vision (fusion)**: Most adult patients will show sensory fusion responses, and even stereopsis, when their angles of misalignment are reduced to under 10 prisms diopters.

- **Restoring the static field of binocular vision**: Realigning an eye restores the normal “panorama” of the binocular visual field, which can be significantly contracted in esotropia and abnormally expanded in exotropia.

- **Restoring the dynamic field of binocular single vision**: In cases where the misalignment causes diplopia, surgery can expand the single vision field back to a useful range, thus reducing the level of disability and allowing the patient to more efficiently perform activities of daily living.

- **Improving psychosocial functioning**: Realigning an eye reverses many of the negative social and psychologic
stresses that affect adults with strabismus. Numerous studies have shown the positive gains, using indicators including employability, self-esteem, improved interpersonal relationships, and self-confidence.

- **Quantitating cost-effectiveness**: Cost-utility analyses have confirmed that adult strabismus surgery is highly cost-effective. In addition, visual function studies have shown negative subjective and quantitative effects on quality-of-life measures in adults with strabismus.

**ACKNOWLEDGMENTS**

The author thanks Drs Agnes Wong and David Smith for reviewing the manuscript and making helpful suggestions, and Frances Kraft for editorial assistance.

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