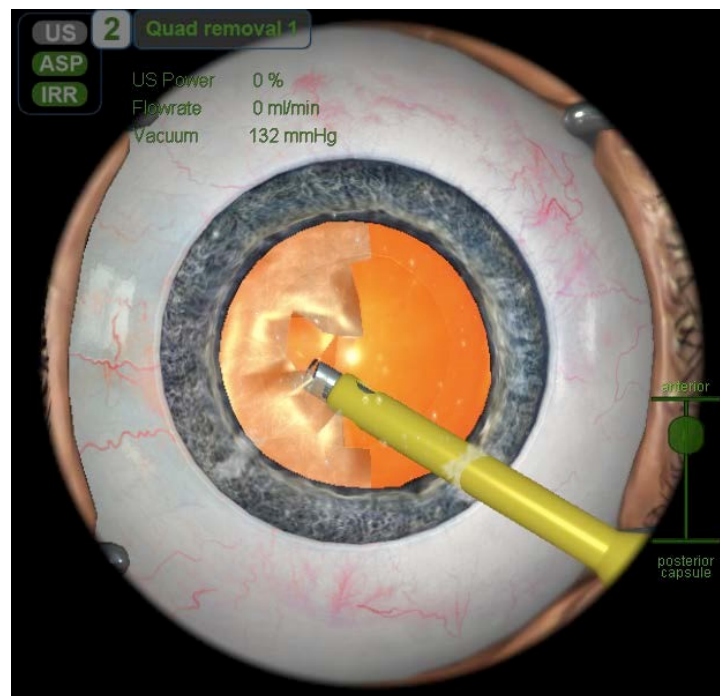




# The Virtual Cataract Surgery Course Manual for Ophthalmology Residents

2018 Edition



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# Disclosure

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**Disclaimer:** The views expressed in this course are those of the authors and do not necessarily reflect the position or policy of the United States (US) Department of Veterans Affairs or the US Government.

All screen shots of the virtual simulator have been used with permission of VRmagic (Mannheim, Germany).

*This course is dedicated to Carly J Seidman, MD  
without whom the ophthalmic virtual surgery  
program at Brown would still be virtual*

*The authors thank David R Rivera, MD  
for his contributions to this course manual*

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## COURSE OVERVIEW

Welcome to the Virtual Cataract Surgery Course at the Division of Ophthalmology of Alpert Medical School. This manual provides ophthalmology residents with an overview of cataract surgery and an opportunity to practice microsurgical skills in preparation for the operating room.

There are two components to this course: didactics and virtual surgery. The didactics portion introduces the lens, cataract surgery procedure, pre-operative and post-operative care of patients undergoing cataract surgery, and complications of cataract surgery. There is also a set of tips covering all the stages of cataract surgery for residents by David R Rivera, MD, Clinical Assistant Professor of Surgery (Ophthalmology) at the Alpert Medical School, Brown University. Residents should review the American Academy of Ophthalmology (AAO) Basic and Clinical Science Course® (BCSC), “Lens and Cataract,” [2015-2016]; **all references to book chapters or figures in the manual come from this BCSC text.** Residents should also consult the [AAO Preferred Practice Pattern® Guidelines](#), “Cataract in the Adult Eye” to supplement their learning as outlined in the course.

The virtual surgery portion of the course consists of training with the EyeSi® Simulator (VRmagic, Mannheim, Germany), software version 2.9 and courseware v2.2. This section incorporates training modules designed to improve hand-eye coordination, such as navigation and anti-tremor tasks, and modules that teach different skill sets for the key steps in cataract surgery. Specific learning modules must be completed during each year of the ophthalmology residency. The ordering of tasks within each PGY course reflects their increasing difficulty. PGY2 and PGY3 residents should spend approximately 15 hours of supervised training with the EyeSi® during each year of their training. PGY2 residents are to complete the Cat A and Cat B modules, while PGY3 residents will complete the Cat C and Cat D modules. PGY3 residents will also complete the mental skills curriculum from the Department of General Surgery at the Indiana University School of Medicine. PGY3 residents must pass a practical test at the end of the academic year. PGY4 residents should review the steps they need to improve upon based on their experience in the operating room. Residents may repeat modules as many times as desired on their own time.

Special areas of focus include ergonomics of surgery for the Cat A module, phacodynamics and surgical videos for Cat B, and mental skills training and

surgical videos for Cat C and Cat D. There is a pre-test and post-test specifically for PGY2 and PGY3 residents at the beginning and end of the academic years.

## CATARACT SURGERY SIMULATOR COURSE OVERVIEW

### PGY2

- ∞ Didactic pre-test (Chapters 1-7)
- ∞ EyeSi: CAT A
  - Focus topic: Ergonomics of Cataract Surgery
- ∞ EyeSi: CAT B
  - Focus topic: Phacodynamics and Phaco machine
  - Surgical videos
- ∞ Didactic post-test (Chapters 1-7)

### PGY3

- ∞ Didactic pre-test (Chapters 8 & 9)
- ∞ EyeSi: CAT C
  - Focus topic: Mental Skills
  - Surgical videos
- ∞ EyeSi: CAT D
  - Focus topic: Mental Skills
  - Surgical Videos
- ∞ Didactic post-test (Chapters 8 & 9)
- ∞ Practical test (Thomsen et al., 2015)

| Module                            | Level | Score 1 | Score 2 |
|-----------------------------------|-------|---------|---------|
| Intracapsular navigation training | 2     |         |         |
| Antitremor training               | 4     |         |         |
| Intracapsular antitremor training | 2     |         |         |
| Forceps training                  | 4     |         |         |
| Bimanual training                 | 5     |         |         |
| Capsulorhexis                     | 1     |         |         |
| Phaco divide and conquer          | 5     |         |         |
| TOTAL                             |       |         |         |

### PGY4

- Specific tasks in need of improvement based upon experience in operating room

## LENS ANATOMY (Chapter 1)

- ∞ **Crystalline lens:** transparent, biconvex component of the eye that lies between the iris and the vitreous body
  - Composed of capsule, lens epithelium, cortex, and nucleus
  - Attached to the ciliary body
  - Suspended in position by the Zonules of Zinn (strong, delicate fibers)
  - Avascular; depends on aqueous humor for metabolic needs
  - No innervations
  - Index of refraction 1.4 centrally and 1.36 peripherally; decreases with age due to increasingly insoluble protein particles
  - Size increases throughout life
    - Birth: 6.4 mm equatorially, 3.5 mm anteroposteriorly, 90 mg
    - Adult: 9 mm equatorially, 5 mm anteroposteriorly, 255 mg
  - Curvature increases with age, augmenting refractive power
- ∞ **Lens capsule:** elastic, transparent basement membrane composed of type IV collagen; point of attachment for zonular fibers
- ∞ **Lens epithelium:** single layer of epithelial cells lying directly behind anterior lens capsule; cells generate ATP for the lens
- ∞ **Nucleus and cortex:** new fibers are created at the periphery of the lens, forming the outermost layers of the cortex; over time they crowd and compact the existing ones toward the center (“nucleus”); cortical thickness increases with age
- ∞ Illustration: Figure 1-2 (page 5)

## LENS PHYSIOLOGY (Chapter 2)

- ∞ Maintenance of lens transparency depends on proper lens metabolism
  - Glucose is the primary energy source of the lens
  - Majority of ATP is produced via anaerobic glycolysis—the lens is not dependent on oxygen
    - Glucose deprivation for more than a few hours results in a hazy lens
  - Water and cation balance are necessary for lens transparency
    - Proper gradients are maintained by membrane channels and energy-dependent pumps
- ∞ **Lens Aging:** lens increases in weight and thickness with age; decreases in accommodative power with age
  - Nuclear sclerosis: new cortical fibers compress and harden the lens nucleus
  - High-molecular-weight protein aggregates result from chemical modification and proteolytic cleavage of crystallins (lens proteins)

- Aggregates grow in size and cause abrupt fluctuations in local refractive index of lens, leading to light scattering and decreased transparency
- Chemical modification of crystallins causes lens discoloration, leading to a yellow-brown tint

## LENS EMBRYOLOGY AND DEVELOPMENTAL DEFECTS (Chapter 3)

- ∞ Around day 25 of gestation, two outpouchings of the developing forebrain (“optic vesicles”) extend out to surface ectoderm
- ∞ The optical vesicles induce formation of the lens placode, which transforms into the lens pit and ultimately the lens vesicle
- ∞ Primary lens fibers form the embryonic nucleus. Secondary lens fibers (formed during months 2-8 of gestation) form the fetal nucleus
- ∞ Illustration: Figure 3-1 (page 22)
- ∞ Congenital cataracts occur in 1/2000 live births; may be unilateral or bilateral
  - 1/3 of congenital cataracts are part of a larger syndrome or disease
  - 1/3 of congenital cataracts are an isolated inherited trait
  - 1/3 of congenital cataracts have unknown etiologies
- ∞ Etiologies of unilateral congenital cataracts: ocular anomalies, trauma, rubella, masked bilateral cataract, idiopathic
- ∞ Etiologies of bilateral congenital cataracts: hereditary cataracts, genetic and metabolic diseases (i.e. Down syndrome, galactosemia, Marfan syndrome, Alport syndrome, myotonic dystrophy) maternal infection, ocular anomalies, toxins, idiopathic
- ∞ Ectopia Lentis: congenital, developmental, or acquired displacement of the lens
  - Most common etiology of acquired lens displacement is trauma; others include Marfan syndrome, homocystinuria, aniridia, and congenital glaucoma
- ∞ Genetics of Cataracts
  - Identical and fraternal twin studies and familial associations suggest that a significant proportion of risk of age-related cataracts is inherited
  - Inheritance accounts for >50% of risk of cortical cataracts
  - Inheritance accounts for 35-50% of risk of nuclear cataracts

## LENS PATHOLOGY (Chapter 4)

- ∞ 3 main types of age-related cataracts: nuclear, cortical, and posterior subcapsular

- ∞ **Nuclear cataracts:** excess amount of light scattering and yellowing, causing central opacity
  - Typically progress slowly
  - Usually bilateral
  - Tend to impair distance vision more so than near vision
  - Lenticular myopia: progressive hardening of lens nucleus that causes an increased refractive index of lens, creating a myopic shift in refraction
  - Illustration: Figure 4-2 (page 41)
- ∞ **Cortical cataracts:** local disruption of mature fiber cell structure; compromised membrane integrity leads to essential metabolite loss from affected cells, causing extensive protein oxidation and precipitation
  - Rate of progression varies
  - Usually bilateral, but often asymmetric
  - Glare is a common symptom when the central portion is affected
  - May result in monocular diplopia
  - First signs are vacuoles and water clefts in the anterior or posterior cortex, visible with a slit-lamp biomicroscope
  - Illustration: Figure 4-4 (page 43)
- ∞ **Posterior subcapsular cataracts (PSCs):** located in posterior cortical layer; usually axial
  - Seen more commonly in younger patients than nuclear and cortical cataracts
  - First sign is a subtle iridescent sheen in the posterior cortical layers
  - Glare and poor vision under bright lighting often result; PSCs obscure more of the papillary aperture when miosis occurs
  - May result in monocular diplopia
  - Etiologies include aging; trauma; systemic, topical or intraocular corticosteroid use; inflammation; ionizing radiation; alcohol abuse
  - Posterior migration of lens epithelial cells from the lens equator to the axis on the inner surface of the posterior capsule seen on histology
  - Illustration: Figure 4-8 (page 47)

## EPIDEMIOLOGY OF CATARACTS (Chapter 5)

- ∞ Cataracts are the leading cause of blindness and visual impairment in the world
- ∞ Cataracts affect 1 in 6 people aged 40 years and older in the United States (US)
- ∞ In the US, 5% of 50-year-olds have cataracts, 15% of 60-year-olds, 36% of 70-year-olds, and 68% of 80-year-olds and older (National Eye Institute, 2010)
- ∞ As the population of the US ages, the prevalence of vision loss due to cataracts is increasing

- ∞ Risk factors for cataract development include age, family history of cataracts, diabetes, previous ocular injuries or procedures, and UV exposure
- ∞ Cigarette smoking is another risk factor for cataract development. Smoking cessation lowers the risk of cataracts by limiting the total dose of smoking-related damage to the lens

## PREOPERATIVE CARE (Chapters 6 & 7)

### **Prior to surgery:**

- ∞ Conduct a comprehensive ophthalmic evaluation, including an assessment of how the patient's cataract affects the patient's quality of life
- ∞ Obtain informed consent from the patient or the patient's surrogate decision-maker after discussing the risks, benefits, and expected outcomes of surgery, including the anticipated refractive outcome and the surgical experience
- ∞ Formulate a surgical plan, including selection of an appropriate intraocular lens (IOL)
- ∞ Determine postoperative care plans and discuss these arrangements with the patient or the patient's surrogate decision-maker

### **Anesthesia**

- ∞ Options include general and local anesthesia (i.e., retrobulbar, peribulbar, or sub-Tenons injection, topical). When selecting the appropriate method of anesthesia, consider the patient's needs and preferences as well as the expertise of the anesthesia professional and cataract surgeon
  - The preferred method is local anesthesia
- ∞ Indications for general anesthesia include medical, psychosocial, or surgical factors
- ∞ Discuss the planned method with the patient so he or she will know what to expect in terms of pain, discomfort, consciousness level, visual experiences, and complications

### **Infection Prophylaxis**

- ∞ Identify and minimize infection risk factors. Ensure antisepsis of the periocular surface, usually with povidone-iodine prior to surgery, and make certain that all incisions are closed in a watertight fashion at the end of the procedure
- ∞ Antibiotic use on the day of surgery, rather than waiting until the next day, is important
- ∞ Any additional prophylactic antibiotics are administered at the surgeon's discretion. Topical antibiotics may be administered prophylactically, though no study demonstrates their efficacy in reducing risk of endophthalmitis in routine cataract surgery

## INSTRUMENTS

### A. Surgical instruments

- ∞ Most instruments are held like a pen
- ∞ A relaxed grip improves fine motor control
- ∞ Both hands should be held at the patient's eye level with relaxed shoulders
- ∞ Instrument control comes from the fingers and wrists
- ∞ Instruments should float within the incision and maneuvered without pushing on the incision
- ∞ Instruments are pivoted similar to a paddle in an oarlock
- ∞ To move the instrument to the right within the eye, move the extraocular portion of the instrument to the left
- ∞ Pivoting the instruments is necessary to keep the eye in primary gaze and maintain the red reflex
- ∞ Images and typical uses of the various components of the cataract surgery instrument tray may be found here:

<http://webeye.ophth.uiowa.edu/eyeforum/tutorials/instruments/Phaco/index.htm>

### B. Microscope

1. How to sit at the microscope:
  - ∞ Proper back and neck position are critical to avoiding musculoskeletal disease
  - ∞ First adjust the chair, the table, and the microscope so neutral spinal curvature is maintained throughout surgery

Incorrect position:



Correct position:

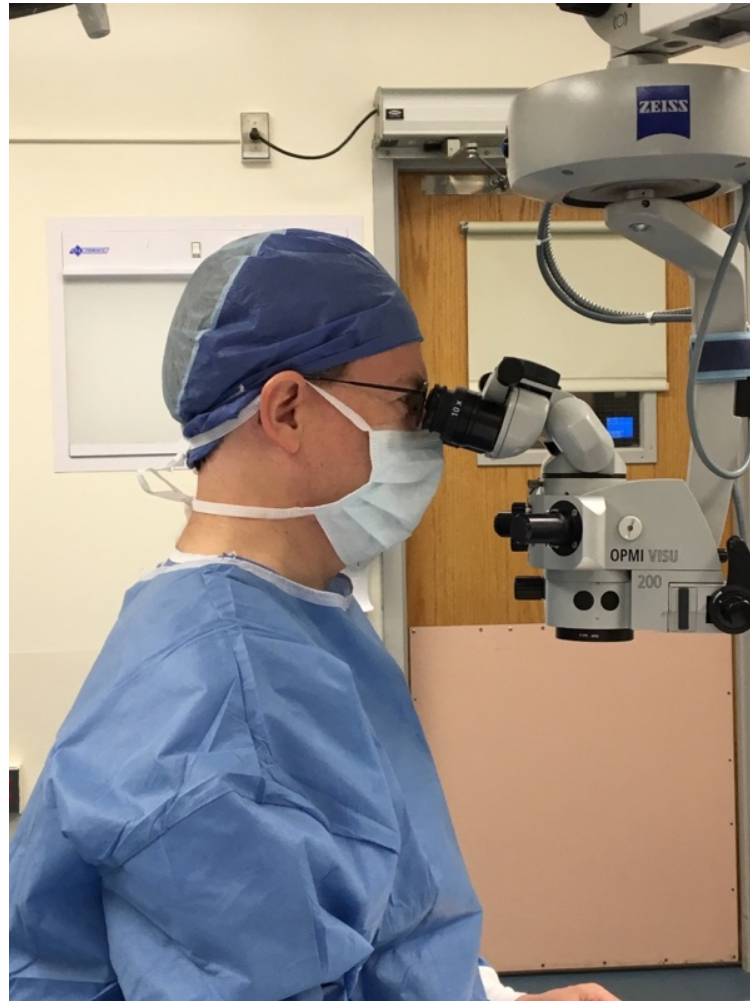


- ∞ When using the foot pedals, lower the seat and table so knees are bent at 90° and thighs are parallel to the floor. The two foot pedals should be at a similar height
- ∞ The microscope should be perpendicular to the plane of the iris
- ∞ Eyepieces should be positioned so the surgeon's head is in neutral position with the neck neither flexed nor extended

Incorrect position:



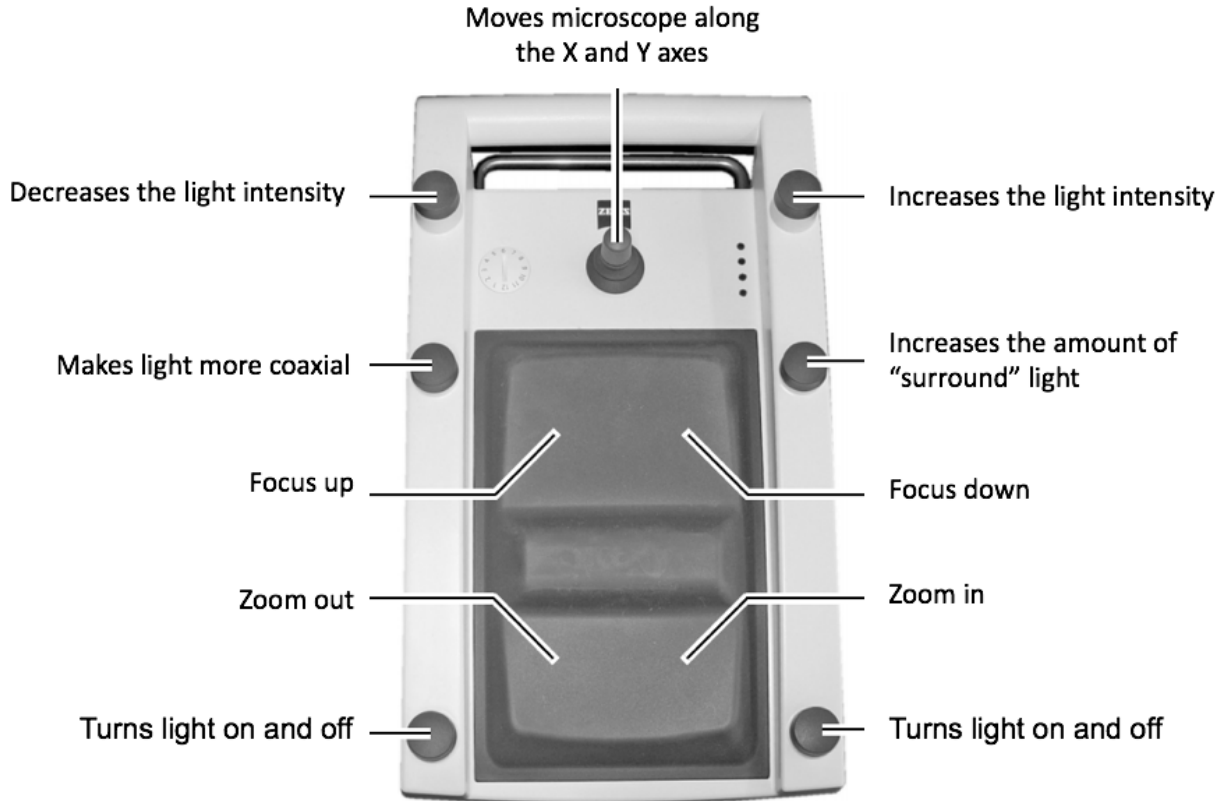
Correct position:



2. How to focus the microscope:
  - ∞ Make sure the pupillary distance is accurate
  - ∞ Zero the microscope by pressing the blue button at the top
  - ∞ Manually move the microscope into position from above to provide a clear image of the conjunctival vessels
  - ∞ Focus up using the foot pedal until the image blurs and then slowly focus down until the image clears to avoid accommodating
  - ∞ Coaxial illumination is used for the steps prior to hydrodissection to improve the red reflex
  - ∞ Paraxial or “surround” illumination is used for the remainder of surgery
  - ∞ Use as little light intensity as needed

### 3. Foot Pedal

OPMI LUMERA® 700 Microscope (Carl Zeiss, Inc., Thornwood, NY, USA) Foot Pedal (current configuration in use as of 2017 at Providence VA Medical Center)



### C. Positioning the Patient's Head and the Stretcher

- ∞ Position the patient so the plane of the patient's face is parallel to the floor
- ∞ The patient's chin and forehead should lie in the same horizontal plane; typically, the patient's neck is slightly extended
- ∞ The patient's head may rest in a neutral position so that there is no rotation to the either the right or the left. It may also be slightly rotated towards the operative eye to reduce pooling of the irrigating fluid
- ∞ A pillow or towel may be placed under the patient's knees to relieve the patient of any uncomfortable back strain
- ∞ A towel may be placed in the space between the stretcher and headrest to relieve the patient of any uncomfortable neck strain
- ∞ It is often helpful to tilt the surgical table so the patient's feet are pointing slightly down in a reverse Trendelenburg position to reduce intraocular pressure and venous congestion in the orbit. This position will also ease breathing in patients with pulmonary disease

- ∞ In patients with severe kyphosis and/or a rigid neck, adjust the stretcher to a Trendelenburg position
- ∞ Video: “02.01 – Surg-onomics” (13 minutes), Unit 2: In the Operating Room and Getting to the Cataract, Introduction to Cataract Surgery, University of Michigan. (Enroll at <https://www.coursera.org/learn/cataract-surgery> for full access to video)

## PHACOEMULSIFICATION (Chapter 7)

The phacoemulsification machine was developed by Dr. Charles Kelman in 1967 and was based on dental equipment used to clean teeth. The machine is composed of two basic elements: ultrasound energy and a fluid circuit. An elevated irrigating bottle provides the fluid volume and pressure. The fluid flows from the irrigation line, through the phacoemulsification tip, out the silicone sleeve ports into the anterior chamber, back into the handpiece, and finally into the aspiration line. The aspiration of the fluid from the anterior chamber is powered by a pump.

### Ultrasonic Terminology

- ∞ **Chatter:** repulsion of the nuclear fragments by the phacoemulsification tip. Increases with increasing phaco power. Overcome by increasing vacuum.
- ∞ **Power:** increased power is produced by increasing the stroke length of the phaco needle. Power is described as a linear percentage of the maximum stroke length of which the needle is capable.
- ∞ **Aspiration flow rate:** the flow of fluid through the aspiration tubing measured in mL/min. Increasing aspiration flow rate quickens the flow of material to the phaco tip.
- ∞ **Occlusion:** obstruction of the aspiration port usually by lens material. Vacuum is increased until the blockage is removed.
- ∞ **Surge:** occurs when occlusion is suddenly broken resulting in negative pressure at the phaco tip. Dangerous as the posterior capsule may be drawn into the tip during surge.
- ∞ **Vacuum:** magnitude of negative pressure in the aspiration tubing. Occurs with occlusion of the tip and determines how firmly the nuclear pieces are held. Measured in mmHg.

A phaco machine can have one of three types of aspiration pumps—peristaltic, diaphragm, and Venturi. The diaphragm pump is no longer in use. The peristaltic pump uses rollers that move along flexible tubing to force fluid through the tubes, creating a vacuum at the aspiration port of the phaco tip. Vacuum rise time is gradual and control is linear as the roller speed increases. The Alcon INFINITY® (Alcon, Fort Worth, TX, USA) uses a peristaltic pump. The Venturi pump generates a vacuum using the Venturi principle—the flow of gas or fluid across a port creates a vacuum proportional to the rate of flow of the gas. Vacuum rise

time is more immediate. The Bausch + Lomb Millennium™ (Bausch + Lomb, Bridgewater, NY, USA) uses a Venturi pump. Both pump types are effective, but most phaco machines are based on the peristaltic design.

The ultrasound energy is produced by a piezoelectric crystal, oscillating between 25,000 and 60,000 times/second (Hz) within the phaco handpiece. This energy is then propagated along the phaco handpiece to the phaco needle. The cataract is emulsified by the acoustic breakdown of lens material, cavitation bubbles at the end of the phaco tip, and the tip's oscillations i.e. "jackhammer" effect.

Constant flushing of the irrigation sleeve around the ultrasound tip with some fluid release through incisions is critical to phacoemulsification. This process maintains anterior chamber depth and cools the phaco probe, preventing heat buildup and resultant damage to surrounding tissue.

Phaco needles (tips) are available in different angles of the tip and sizes of the lumen. The bevel angle is chosen by the surgeon, with the steeper bevels better for cutting and holding nuclear material. The Kelman needle has a distal angulation that produces non-axial oscillation.

Phaco power delivery comes in several forms. Continuous phacoemulsification is used for sculpting the nucleus and occurs when the surgeon applies a constant delivery of power, the degree of which ranges from 0% to 100% depending on how far the surgeon depresses the foot pedal. This form of power delivery allows the surgeon to sculpt deep grooves in the lens nucleus, useful in "divide and conquer" and "stop and chop" techniques. Disadvantages include cavitation, shock waves, shear forces, and heat buildup. Alternate forms of phaco power delivery are pulse and burst techniques. Pulsed phaco sets a certain number of deliveries per second; burst phaco delivers a single spurt of preset power which increases in frequency as the pedal is further depressed. These settings are more energy efficient; pulsed phaco reduces repulsion of material, while burst phaco lets the needle bury into the lens, making chopping possible. Pulse or burst mode should not be used for sculpting, but are more efficient for quadrant removal than continuous mode.

Traditional phaco power is described as "longitudinal." That is, the phaco needle moves back and forth. Torsional phaco (OZI on the Alcon INFINITI® machine) produces oscillation of the phaco tip from side to side. This movement requires less energy to emulsify the lens and therefore carries less risk of thermal burn. Many surgeons use only torsional phaco to remove the lens quadrants after sculpting the grooves with traditional phaco power.

The phaco machine is controlled by the foot pedal. Position 0 refers to the fully upright resting position in which no irrigation is present. By depressing the foot pedal slightly, Position 1 is activated which initiates irrigation. Further depression of the foot pedal results in Position 2 which produces flow through the aspiration port when the tip is not occluded, and vacuum when the tip is occluded. In Position 3, ultrasound energy is produced. In summary, Position 1 = irrigation;

Position 2 = irrigation + aspiration, and Position 3 = irrigation + aspiration + ultrasound.

The phaco machine settings which can be manipulated by the surgeon include bottle height, power, aspiration flow rate, and vacuum. Knowledge of the interaction between these parameters and best settings depending on the phase of cataract material (sculpting vs. lens removal) is imperative to most efficiently remove the cataract with the smallest chance of complications. This logic of setting machine parameters is referred to as “phacodynamics.”

When sculpting the nucleus, the surgeon wishes to cut the nucleus in place. Thus, the vacuum and aspiration flow rate are relatively low. With a low flow rate, the bottle height can be moderate and still provide for a stable anterior chamber. The phaco power, which should only be used on each forward cutting stroke, should not be too low, which would result in pushing rather than cutting the nucleus, and not too high, which would predispose to corneal damage and wound burn. Often, a maximum power is set and then the power is controlled as required with the pedal.

During quadrant removal, aspiration flow rate and vacuum are increased and power can be decreased. The bottle height is increased to maintain anterior chamber depth. With only one or two remaining quadrants, the aspiration flow rate can be reduced to reduce tumbling of the remaining pieces.

In general, as nuclear density increases, more phaco power is needed which requires a proportional increase in the aspiration flow rate and vacuum settings.

Detailed knowledge of these parameters and their interplay is necessary to become an excellent phaco surgeon. A resident entering the operating room for the first time must understand phacodynamics and which settings to use.

## **CATARACT SURGERY PROCEDURE (Chapter 7)**

### **Background**

Cataract surgery has evolved over centuries into a modern technique called phacoemulsification (phaco). This method uses an ultrasonically-driven tip to fragment the cataract nucleus before emulsifying the pieces and removing them via an automated irrigation aspiration system. Phaco incisions and techniques are minimally invasive, allowing for fewer wound-related complications, faster healing, and more rapid visual rehabilitation than procedures requiring larger incisions. Additionally, phaco maintains a relatively closed system throughout surgery to control anterior chamber depth and safeguard against positive vitreous pressure and choroidal hemorrhage.

## Basic Procedure Outline

- ∞ **Pupillary dilation:** use mydriatic/cycloplegic drops
- ∞ **Exposure of the globe:** use a lid speculum to hold eyelids apart. Superior approach phaco procedures may use a bridle suture to stabilize and expose the globe
- ∞ **Paracentesis:** use a sharp blade to create a small paracentesis adjacent to the planned handpiece incision site. Instill an ophthalmic viscosurgical device (OVD) to protect intraocular structures and allow for more control during incision
- ∞ **Incision:**
  - **Scleral tunnel incision:** superiorly-placed scleral tunnel incision with an internal corneal lip; commonly used by novice phaco surgeons
  - **Clear corneal incision:** small incision just large enough to accommodate the phaco needle and a foldable intraocular lens (IOL) used by most experienced phaco surgeons; based on surgeon preference, incision can be made superiorly, temporally or at the cornea's steepest axis
- ∞ **Continuous curvilinear capsulorhexis (CCC):** use a cystotome needle or capsulorhexis forceps with special tips for grasping and tearing to create a central curvilinear tear in the anterior capsule
  - Loose zonules may impede CCC. Capsular hooks may stabilize the bag to allow tear completion
  - Surgeons may convert to a can-opener anterior capsulotomy if they cannot complete a CCC
- ∞ **Hydrodissection:** place a flattened hydrodissection cannula attached to a syringe under the anterior capsule flap to gently inject irrigation fluid. This separates the peripheral cortex from the underlying posterior lens capsule
  - Hydrodissection loosens the lens nucleus and cortex to allow nuclear rotation during phaco
  - Hydrates the peripheral cortex, making aspiration after nucleus removal easier
- ∞ **Nuclear rotation:** successful hydrodissection breaks posterior cortex and posterior capsule attachments, enabling rotation of the nucleus within the capsular bag
- ∞ **Emulsification:** use ultrasound from the handpiece to break up the cataract

- Possible locations: anterior chamber, iris plane, and posterior chamber
- **Anterior chamber:** prolapse the nucleus into the anterior chamber before emulsification
  - Advantages: excellent visualization; minimized risk of damage to posterior capsule
  - Disadvantages: increased risk of corneal endothelial trauma and resultant corneal edema
- **Iris plane:** prolapse the superior pole of the nucleus anteriorly and emulsify halfway between the corneal endothelium and the posterior capsule to reduce risk of damage to either structure
  - Advantages: reduces stress on posterior capsule and zonular fibers during nuclear manipulation; maintains visualization in cases with small pupils; desirable for novice phaco surgeons in more difficult cases
  - Disadvantages: difficulty in prolapsing nucleus; potential damage to corneal endothelium if superior pole of nucleus is emulsified too close to cornea
- **Posterior chamber:** method includes capsulorhexis, hydrodissection, and nucleus rotation. Most common method
  - Advantages: reduces risk of corneal endothelial trauma;
  - Disadvantages: emulsification close to the posterior capsule increases chance of rupture of the posterior capsule; difficult in cases with small pupils; requires more sophisticated nuclear splitting methods

∞ **Nucleus disassembly:**

- **One-handed technique:** one surgical incision following adequate capsulorhexis. Then, use the phaco needle to remove the epinuclear envelope with low power and medium vacuum settings. Use irrigation/aspiration to remove residual cortex
- **Two-handed technique:** uses two instruments within the eye to remove the lens. There are many different ways of removing the lens, such as divide and conquer, horizontal chopping, and vertical chopping
  - **Divide and Conquer technique:** sculpt a central linear groove deep enough for subsequent cracking. Crack the nucleus into two pieces or divide the intact nucleus into quadrants. Then, use a second instrument to present a quadrant to the phaco needle for emulsification. Repeat for the other three quadrants; most widely-used technique for all but very soft cataracts
  - **Chopping techniques:** bury the phaco tip in the center of the nucleus using high vacuum. Then, insert a phaco chop instrument under the anterior capsule flap, deeply engage the endonucleus in the periphery, and draw it toward the

phaco tip to crack the nucleus into two pieces. Repeat on each piece to create small wedges for emulsification

- “Stop and chop”: modified procedure that involves the creation of a central groove first followed by division of the nucleus into 2 pieces through sculpting and cracking before chopping of each heminuclei
- Need high vacuums to maintain firm control and reduce ultrasound energy
- Not appropriate for soft nuclei

## POSTOPERATIVE CARE

### Postoperative Follow-Up Care

- ∞ Inform the patient about appropriate signs and symptoms of possible complications, eye protection, appropriate activities, medication, required visits, and details for access to emergency care
- ∞ Inform patients of their responsibility to follow provided advice and instructions. Patients should always have access to an ophthalmologist for appropriate care if serious problems arise; inform the patient that he or she should notify an ophthalmologist immediately if problems arise
- ∞ Determine the frequency of postoperative exams based on optimizing the outcome of surgery and minimizing/managing complications. Patients are routinely followed up within 24 hours of surgery. Subsequent visits are based on post-operative signs and symptoms
- ∞ Patients should make a final visit to obtain an accurate post-operative refraction when the prescription has stabilized. This usually occurs within 1-2 months after surgery

### Postoperative Medication

- ∞ Evidence varies for postoperative regimens of topically applied antibiotics, corticosteroids and NSAIDs. Use discretion when deciding to use any topical agent(s)

## RESIDENT TIP SHEET (David R Rivera, MD)

### At pre-op appointment:

- ∞ The most important clinical elements to note about a prospective cataract patient are:
  1. Ocular comorbidities, particularly things that will affect:
    - a. visual potential – amblyopia, AMD, Fuch’s, etc.
    - b. ability to get good biometry – dry eye, corneal shape, dense lens
    - c. surgery – small pupil, PXF, trauma, corneal clarity

2. Alpha-blocker use history and size of dilated pupils
3. Current refractive status

- ∞ Make sure the biometry is good, especially the keratometry.
- ∞ Prepare your counseling talk. Use pictures/models to explain the procedure, risks and postoperative course.
- ∞ Before the end of the day, discuss clinical issues and make surgical plan, pick IOLs, complete H&P/consults/orders.

### **Day before surgery**

- ∞ Consider calling the patient to make sure they will show up. Check that the H&P and consent are up-to-date. If not, will need to be updated on a.m. of surgery.

### **Morning of surgery**

- ∞ Arrive early, preferably at or before 7AM.
- ∞ Start your preop notes and brief op notes.
- ∞ Draw up 10 mL of 0.75% Marcaine™ (Hospira, Inc., Lake Forest, IL, USA) for subconj block.
- ∞ Make epi-Shugarcaine.
- ∞ Make sure microscope and foot pedals are set up correctly for OD or OS.
- ∞ Make sure phaco machine is on settings for your attending.
- ∞ Do your long scrub.
- ∞ Help the scrub and circulator with set up

### **The case**

- ∞ Help position the stretcher in the correct spot relative to the microscope.
- ∞ Help position the patient at the head of the bed and instill tetracaine.
- ∞ For toric IOL cases, help situate the patient in a seated position, anesthetize and mark the cornea. The marker will be handed off the surgical table along with 2 spear sponges (Weck-Cel®; Beaver-Visitec International, Inc., Waltham, MA, USA). Have the patient look ahead with both eyes open. Place ink on the 3 fins of the marker. Hold the lids apart and dry the 3, 6 and 9 o'clock areas with the sponge. Without letting go of the lids, mark the cornea and dry the marks with the sponge. Then lower the head and get the patient into position.
- ∞ Have the selected IOLs and calculation sheet at the bedside for the timeout.
- ∞ Prep the patient- Betadine® (Purdue Pharma, L.P., Stamford, CT, USA) solution on the periocular surfaces, lashes cleaned with Q-tips and half-strength Betadine® drops on the ocular surface. Dry well.
- ∞ Fenestrated drape over eye and Tegaderm™ (3M, St. Paul, MN, USA) to drape the lashes. Insert speculum.
- ∞ Ensure phaco machine is set for surgery.
- ∞ Warn patient of discomfort. Inject subconj block- 0.2-0.3 mL Marcaine™. Spread.

- ∞ Paracentesis incision(s) at the limbus with 1 mm angled blade. Direct blade parallel to the iris plane.
- ∞ Warn patient of discomfort then gently inject epi-Shugarcaine followed by Viscoat® (Alcon, Fort Worth, TX, USA), an ophthalmic viscosurgical device (OVD) with dispersive properties. Insert Viscoat® cannula across the anterior chamber and inject to force bubbles back to the wound. Fill until cornea is firm (needed to make keratotomy).
- ∞ If trypan blue (VisionBlue®; DORC International BV, Zuidland, Netherlands) is to be used, follow the epi Shugarcaine with air, then trypan, then Viscoat®.
- ∞ Make a triplanar incision with 2.75 mm keratome.
- ∞ Start the capsulorrhexis with a cystotome and complete with capsulorrhexis forceps. When advancing the rhexis, always make sure the flap is on its back. Grasp the flap edge near the tear. The angle between the lens surface and the flap should be < 45 degrees to allow for the best control of the tear. When the distance between the forcep and the tear becomes long, there is less control. Place the flap in an advantageous position before letting go for a re-grasp. Know the Little rescue technique.
- ∞ Hydrodissect with the flat, Chang hydrodissection cannula. Insert the cannula just under the edge of the anterior capsule (not into the cortex). Inject in multiple locations watching for a fluid wave behind the lens. When the lens moves anteriorly, stop injecting and press down on the lens (ballotement) to release the fluid from behind the lens. Ensure free rotation of the lens with the tip of the cannula. Place the tip of the cannula as peripheral as possible to create a larger lever arm and therefore, less force for rotation.
- ∞ Phaco the lens. Multiple techniques. Basic principles: When sculpting or grooving, keep depth of the phaco needle bevel at 1/2-3/4 as you do not want to occlude. When emulsifying fragments, you want occlusion for most efficient phacoemulsification. Mind the occlusion break – when the lens material is occluding the tip, vacuum builds in the tubing. When it is emulsified sufficiently to be aspirated into the needle, the occlusion is broken and the built-up vacuum will cause a surge of inflow into the needle. If the needle is near the capsule, this could draw in the capsule potentially tearing it. To avoid this, phaco at or above the plane of the anterior capsule. Make sure the inflow (controlled by bottle height) is sufficient to keep the capsule inflated and deep. Keep your second instrument between the needle and the capsule to block the capsule from coming to the needle.
- ∞ Use I/A (irrigation/aspiration) to remove the cortex. Keep the port of the I/A handpiece facing up. Grab the cortex on the underside of the anterior capsular leaflet and strip by pulling centrally. When using coaxial I/A, remove the sub-incisional cortex first. This is the hardest part to remove because you must turn the handpiece around to have the port facing you and not directly up. Having cortex in the remainder of the capsular bag keeps it more stable as you try to remove the sub-incisional component.

- ∞ Fill the capsule with Provisc® (Alcon, Fort Worth, TX, USA), an OVD with cohesive properties. The chamber is typically shallow when you enter with the cannula. Be careful not to hit the posterior capsule. Make sure you see the posterior capsule moving back as you begin to inject; this verifies that the bag – not the sulcus – contains the OVD.
- ∞ Inject the IOL. Rotate as needed.
- ∞ I/A the residual OVD. Place the I/A tip right down on the IOL and aspirate pedal to the metal to try to get OVD to come out from behind the IOL (IOL will shimmy back and forth as OVD burps up around sides of IOL). If necessary, go behind the IOL with the handpiece to remove retained OVD. Withdraw the I/A handpiece smartly so hopefully the AC won't collapse.
- ∞ Fill the AC via the paracentesis and seal with stromal hydration. Check for leakage. Stromal hydrate the main wound if not sealed. If stromal hydration fails to seal the wound, suture it. 10-0 Vicryl® (Ethicon US, LLC, Somerville, NJ, USA) or nylon and bury the knot.

## COMPLICATIONS OF CATARACT SURGERY (Chapters 8 & 9)

- ∞ **Corneal edema:** (0.3% complication rate) stromal and/or epithelial edema occurring immediately in the post-operative period
  - Frequently caused by a combination of mechanical trauma, prolonged surgery, inflammation, and elevated intraocular pressure (IOP)
  - Trauma-induced edema usually resolves completely within four to six weeks of surgery
  - Epithelial edema presenting with a compact stroma immediately after surgery suggests the cause to be elevated IOP with intact endothelium
  - If corneal periphery is clear, corneal edema will resolve with time. Corneal edema lasting for more than three months usually does not clear, and may require surgical intervention to correct
  - In early stages, control of corneal edema includes use of topical hyperosmotic agents, topical corticosteroids and bandage (therapeutic) contact lenses
  - Illustration: Figure 8-1 (page 147)
- ∞ **Capsular opacification and contraction:**
  - Posterior capsule opacification: due to continued viability and proliferation of lens epithelial cells remaining after removal of nucleus and cortex. These cells can undergo metaplasia and conversion to fibroblasts, which create a matrix of fibrous and basement membrane collagen that can contract to cause wrinkles in the posterior capsule. Results in distorted vision and glare

- Most common complication of cataract surgery by means of extracapsular cataract extraction (ECCE) or phacoemulsification
  - Risk is minimized by hydrodissection and careful cortical cleanup
- Anterior capsule fibrosis and phimosis: capsular fibrosis refers to clouding of the anterior capsule. Symptoms include glare (especially at night) and the sensation of a peripheral haze. Capsular phimosis indicates shrinking and distortion of the anterior capsule opening due to fibrosis, revealing capsular tissue through the undilated pupil
  - Phimosis usually causes more pronounced symptoms than fibrosis
  - Treatment (for symptomatic patients) consists of a Nd:YAG laser anterior capsulotomy to enlarge the anterior capsule opening
- ∞ **Hemorrhage:** patients on anticoagulant or antiplatelet therapy during cataract surgery do NOT have increased risk of hemorrhagic complications. Possible locations include:
  - Retrobulbar hemorrhage
  - Suprachoroidal effusion or hemorrhage
  - Expulsive suprachoroidal hemorrhage
  - Delayed suprachoroidal hemorrhage
  - Anterior chamber (hyphema)
- ∞ **Endophthalmitis:** (0.17-0.2%) vitreous inflammation with possible eyelid or periorbital edema, ciliary injection, chemosis, anterior chamber reaction, hypopyon, decreased visual acuity, corneal edema, or retinal hemorrhages
  - Acute or chronic/indolent
  - Symptoms include mild to severe ocular pain, loss of vision, floaters, and photophobia
  - Key prevention measure: careful attention to watertight incision closure
    - Preoperative application of topical therapy for three days can reduce bacterial counts, but studies have not shown a subsequent decrease in infection incidence
    - Preliminary study suggests that 1 mg cefuroxime injected into the anterior chamber at the end of cataract surgery can reduce endophthalmitis incidence by five-fold
    - 5% povidone iodine on the eye 20 minutes before surgery also reduces risk of endophthalmitis
  - Treatment: assess visual acuity to make management decisions
    - When vision has been reduced to light perception, pars plana vitrectomy with vitreous biopsy and administration of intravitreal antibiotics is indicated

- When vision is hand motion or better, a vitreous tap with injection of intravitreal antibiotics is indicated
- Administer topical (and subconjunctival) antibiotics and topical steroids; oral antibiotics with good vitreous penetration may also be considered.
- Intravitreal corticosteroids to decrease inflammation and scarring may be considered
- ∞ **Cystoid macular edema (CME):** (3.3%) increased perifoveal capillary permeability causing decreased vision after cataract surgery
  - Characteristic petaloid appearance of cystic spaces in the macula on ophthalmoscopy or fluorescein angiography, or by characteristic retinal thickening on OCT
  - May manifest as loss of contrast sensitivity even with preserved visual acuity
  - Incidence peaks 6-10 weeks after surgery
  - Spontaneous resolution occurs in 95% of uncomplicated cases, usually within six months
  - Risk factors for CME: absence of intact posterior capsule, poorly controlled postoperative inflammation, pre-existing epiretinal membrane, diabetes mellitus, and a previous occurrence of CME
  - Can reduce risk of CME with preoperative and postoperative prophylactic use of topical/systemic indomethacin or topical ketorolac
  - Treatment: corticosteroid and nonsteroidal anti-inflammatory drops are first-line options for patients with persistent CME
- ∞ **Retinal detachment:** (0.37~0.9%) often occurs within six months of cataract surgery or following posterior capsulotomy
  - Risk factors: axial myopia (>25 mm), <50 years old, lattice degeneration of retina, previous retinal tear or detachment in surgical eye, history of retinal detachment in fellow eye, and family history of retinal detachment
  - Risk of retinal detachment increases four-fold following Nd:YAG laser posterior capsulotomy

## MENTAL SKILLS TRAINING

Mental skills training is an emerging component of surgical education. It consists of psychological techniques and strategies to help surgeons consistently perform their best. Techniques include stress-coping and performance-enhancing tools. The goal is to attain an ideal performance state or a feeling of relaxed concentration. Being mentally prepared means achieving a clear image of the desired outcomes, trusting the self to perform its best, learning from previous experiences, and thinking objectively and non-judgmentally. These methods are commonly used in athletics and military training.

An excessive amount of stress decreases surgical performance. Under stressful circumstances, a surgeon should utilize a trigger that will calm the resultant rapid heart rate and shallow breathing, and shift attention to the appropriate goal. A “trigger breath,” or belly breathing, slows the rhythm of breathing and can help in centering focus and achieving a sense of calm. Lastly, shifting one’s attention to a specific detail such as counting the rise and fall of your breaths or repeating a mantra – such as “center,” or “calm,” can discourage negative thoughts and self-criticism.

Performance enhancement techniques include attention management, increasing mindfulness, and thought management. A surgeon needs to limit his or her attention to the performance of surgery and ignore distractions. The less “self-talk” a surgeon does, the more he or she can concentrate on the task at hand. When a surgeon is distracted, it is important to interrupt the current pattern of thinking and refocus attention back on the task at hand. Focus means keeping one’s thoughts in the here and now. When practicing mindfulness, surgeons are fully engaged in the present with sustained focus and non-judgmental thinking. It is important to focus on what the surgeon wants to happen instead of what he or she does not want to happen.

Mental imagery is another mental skill which utilizes mental practice or “visualization” prior to a procedure. By imagining a surgery beforehand (using the entire range of senses), the identical neural pathways that would be activated by the live surgical experience are activated. Through mental imagery, a surgeon can rehearse the physical and mental requirements for peak performance. Each surgeon can create his or her own script with visual, cognitive, proprioceptive, emotional, and other sensory cues to rehearse before surgery. This technique, when associated with traditional surgical training, has been shown to increase surgical performance.

PGY3 residents will complete the mental skills curriculum from the Department of General Surgery at the Indiana University School of Medicine. One module will be viewed and discussed with each PGY3 resident at every simulator session.

#### Further Reading:

Anton NE, Bean EA, Hammonds SC, Stefanidis D. Application of Mental Skills Training in Surgery: A Review of Its Effectiveness and Proposed Next Steps. *J Laparoendosc Adv Surg Tech*. 2017;27(5): 459-469.

Stefanidis D, Anton NE, McRary G, Howley LD, Pimentel M, Davis C, Brown C. Implementation results of a novel comprehensive mental skills curriculum during simulator training. *Am J Surg*. 2017;213(2): 353-361.

Gallwey, W. T. (2015). *The inner game of tennis: the ultimate guide to the mental side of peak performance*. London: Pan Books.

## SURGICAL VIDEO BANKS

- ∞ The Video Atlas of Eye Surgery (EyeMovies Ltd, Godalming, Surrey, United Kingdom)
- ∞ EyeRounds, University of Iowa Department of Ophthalmology and Visual Sciences. Available: <http://webeye.ophth.uiowa.edu/eyeforum/video/INDEX.htm>. [Accessed July 15, 2017].
- ∞ Introduction to Cataract Surgery, University of Michigan. Available: <https://www.coursera.org/learn/cataract-surgery>. [Accessed July 15, 2017].
- ∞ Eyetube.net. Available: <http://www.eyetube.net>. [Accessed July 15, 2017].
- ∞ American Academy of Ophthalmology (AAO). Available: <https://www.aao.org>. [Accessed July 1, 2017].

## INTRODUCTION TO THE VIRTUAL SURGERY SIMULATOR

The virtual surgery portion of this course provides navigation through the EyeSi® cataract surgery tasks designated for each PGY year.

First read through the following sections for a general overview of the EyeSi® system. After reading the instructions for operating the simulator, residents may use this manual as a reference while they perform the tasks.



## The EyeSi® Simulator

The EyeSi® simulator consists of two basic elements: the graphic user interface (touch screen) and the virtual surgical environment (visual field through the microscope). The graphic user interface serves as the control unit and enables users to log in, start training tasks, and configure instruments. The virtual surgical environment contains a computer-graphic presentation of the eye, which appears once the user has started a task.

### Safety Information

- Do not use sharp objects, such as a pen, to touch the screen. Use only your fingers. Do not press hard on the screen.
- Head model
  - Do not reach inside the head model, and avoid penetration of any objects or fluids.
  - Only insert EyeSi® instruments through the pre-made holes in the silicone pads surrounding the eye.
  - Never leave the instruments hanging in the holes without support. Pull instruments out completely when not in use.

### Power On and Log In

- First, make sure the cataract head model is plugged into the USB port on the blue box (there is also a vitreoretinal head).



- To turn on the EyeSi®, hit the power button on the blue box. The red light will turn on first, then the yellow light, and finally the steady green light.



- Now turn on the touch screen monitor. There are five round buttons on the side of the monitor. Hit the lowest button to turn on the screen.



- The log-in screen will now appear.
- Usernames and passwords for each resident level (PGY2, PGY3, PGY4) are listed separately under the appropriate sections.

## OPERATING THE MICROSCOPE

- Upon starting each task, you will have to zoom and focus the microscope on the virtual eye. Make sure the microscope is properly adjusted before you begin any task.
- To adjust the height of the microscope, use the “up/down” button on the platform.
- At the start of each task, select the “microscope” tab.
- To zoom in or out, use your left foot to touch the “Zoom ↑” or “Zoom ↓” buttons on the floor. Always zoom first, then focus.
- To focus up or down, use your left foot to touch the “Focus ↑” or “Focus ↓” buttons on the floor.
- You can also center the virtual eye in the microscope by using the joystick by manipulating it with your left foot.



## OPERATING THE PHACO MACHINE

- Once you have started a task, the “OR Machine” tab in the upper right-hand corner will bring you to the following screen. There, you can adjust the phaco machine to settings that are appropriate for each task.



### Phaco Power and Rate

- The “Phaco” area of the screen lets you adjust the ultrasound power. Make sure to minimize the amount of ultrasonic energy you introduce into the eye while maintaining sculpting ability. Excess energy damages structures and tissues, such as the endothelium.
  - Start with a conservative power level and increase incrementally if you have trouble sculpting the cataract. The phaco tip should be able to emulsify the cataract without pushing it away.
  - The “Linear” setting allows you to deliver an incremental amount of ultrasound energy depending on your foot pedal position. Under the “Fixed” setting, when the pedal enters Position 3, you will deliver a fixed amount of ultrasound energy.
- There are three methods of introducing ultrasound energy—continuous, pulse and burst.
  - In continuous mode, the energy level increases as the foot pedal is depressed.
  - In pulse mode, you can set the frequency of energy pulses delivered and adjust the energy level with the foot pedal; the energy is always delivered in pulses.

- In burst mode, you can set the energy level and adjust the frequency of energy delivery with the foot pedal; the energy level remains constant.

### **Irrigation Height**

- The “Irrigation” area of the screen allows you to determine the bottle height (and subsequently the amount of fluid) you introduce through the handpiece. Increasing the value of the height setting increases the amount of fluid entering the eye.

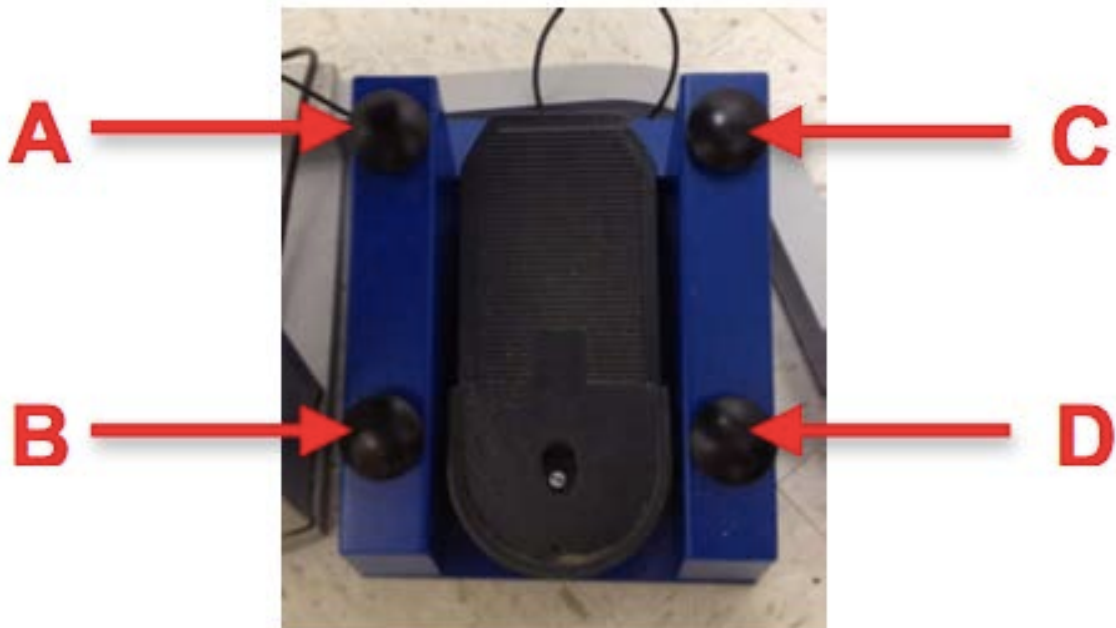
### **Aspiration Vacuum and Flow**

- The “Aspiration” area of the screen lets you adjust the vacuum pressure and the aspiration through the handpiece.
  - The higher the vacuum setting, the greater your ability to hold onto pieces of cataract. You are able to reach your set level of vacuum pressure when you fully occlude the handpiece tip with the cataract.
  - The higher the aspiration setting, the greater the rate with which you remove fluid from the eye. This will affect how quickly pieces of the nucleus flow to the tip. The aspiration rate should not exceed your ability to replace the fluid volume, so adjust your “Irrigation Height” setting accordingly.
- When you set the vacuum and flow to “Linear,” you are able to adjust them through your foot pedal as you can with your phaco power.

### **Presets**

- Preset 1: Sculpting
  - Power = 55 [µm], Pulse Mode
  - Irrigation Height = 80 [cm], Continuous
  - Aspiration Vacuum = 60 [mmHg], Fixed
  - Aspiration Flow = 22 [ml/min], Fixed
- Preset 2: Quadrant Removal
  - Power = 55 [µm], Pulse Mode
  - Irrigation Height = 100 [cm], Continuous
  - Aspiration Vacuum = 300 [mmHg], Fixed
  - Aspiration Flow = 30 [ml/min], Fixed
- Preset 3: Ignore
- Preset 4: Irrigation/Aspiration (I/A)
  - Irrigation Height = 100 [cm], Continuous
  - Aspiration Vacuum = 600 [mmHg], Linear
  - Aspiration Flow = 34 [ml/min], Fixed

## Foot Pedal



- **Positions**

- 1 = a little pressure on the foot pedal will initiate irrigation (IRR); you will see an oval turn green in the upper left-hand corner of your microscope screen when you operate
- 2 = slightly more pressure will initiate aspiration (ASP); you will continue to irrigate at the level you set on the OR machine screen; you cannot aspirate without simultaneously irrigating
- 3 = even more pressure on the foot pedal will initiate ultrasound emulsification (US); at this position, irrigation and aspiration will continue at the level you set on the OR machine screen; you cannot use ultrasound energy without simultaneously irrigating and aspirating

- **Knobs**

- A = increases the preset number by 1
- B = decreases the preset number by 1
- C = increases irrigation bottle height by 5
- D = decreases irrigation bottle height by 5

## TRAINING COURSES

- You are now ready to start the simulations. For each resident PGY level, please turn to the appropriate portion of the course (see table of contents).
- For each task listed, you will have the following information:
  - *Goal*: the objective/desired endpoint of the task
  - *Screenshots*: images of the task at hand
  - *Instruments*: instruments you will need to perform each task. There are three different colored ports on the EyeSi®: yellow, blue and red. Each port becomes a specific instrument depending on the task and module. When viewed through the microscope, the ports will function as instruments, such as forceps, pointers, etc.



- *Instructions*: descriptions of how to perform the task
- *Tips*: advice that may help you in performing the task

## GETTING STARTED

### Logging In

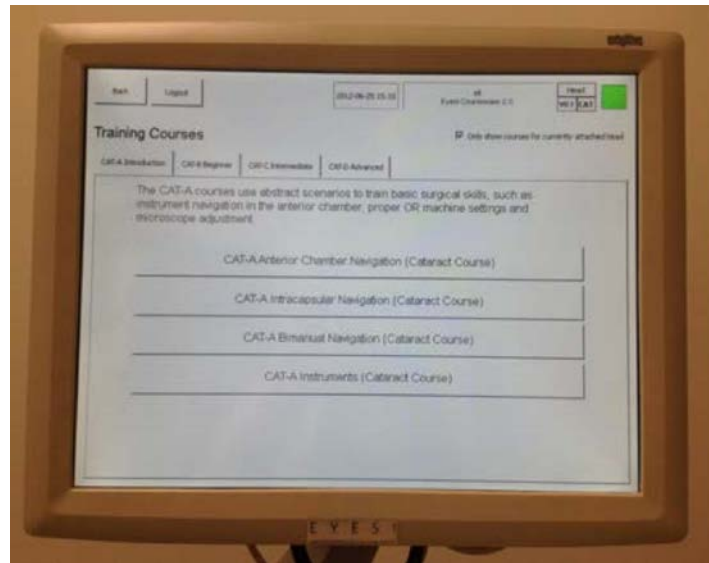
- Turn on EyeSi® and at the log-in screen, enter:
  - User: the first letter of your first name + your last name
  - Password: “eyesi”; you will receive a prompt to change the password once you have successfully logged in



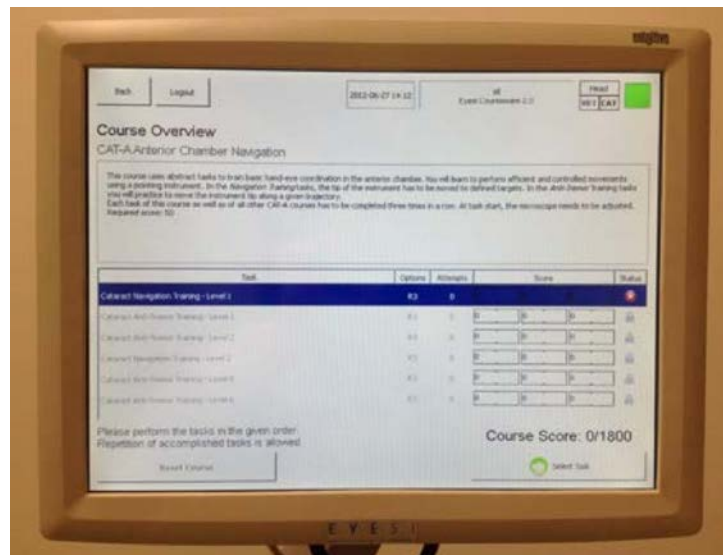
- If you are shown a “Login Failed!” message, try again more slowly with the tip of your finger.
- You will be brought to the main screen. Select “Courses”



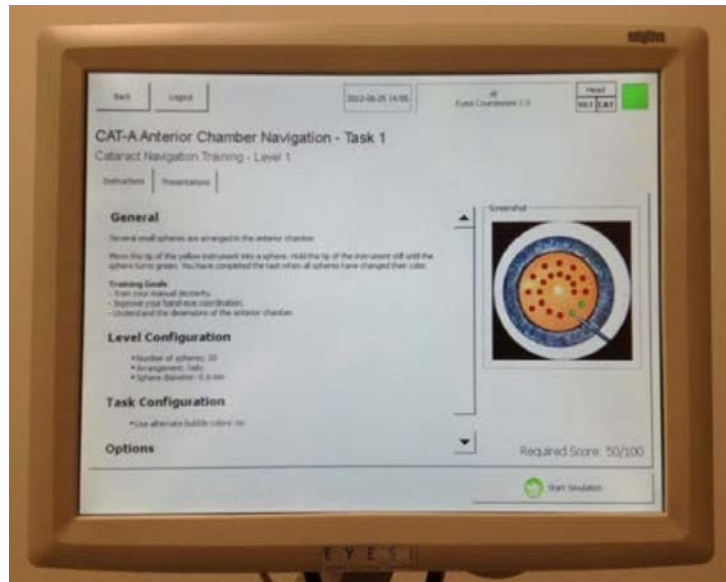
- Select the “CAT-A Introduction” tab and the top course, “CAT-A Anterior Chamber Navigation (Cataract Course).”



- You will see the “Course Overview” page with the list of tasks you will perform during training. To open any task, touch the task to highlight it and press “Select Task” at the lower right-hand corner of the screen.



- You will then see the task description page, where you can select different tabs to view “Instructions” and “Presentations.” (Some tasks have slide presentations and animations that you can view.) Once you have read through the various tabs, select “Start Simulation” to begin the task.



## PGY2 COURSES

### CAT-A INTRODUCTION

CAT-A courses use abstract scenarios to train basic surgical skills, such as instrument navigation in the anterior chamber, proper machine settings, and microscope adjustment.

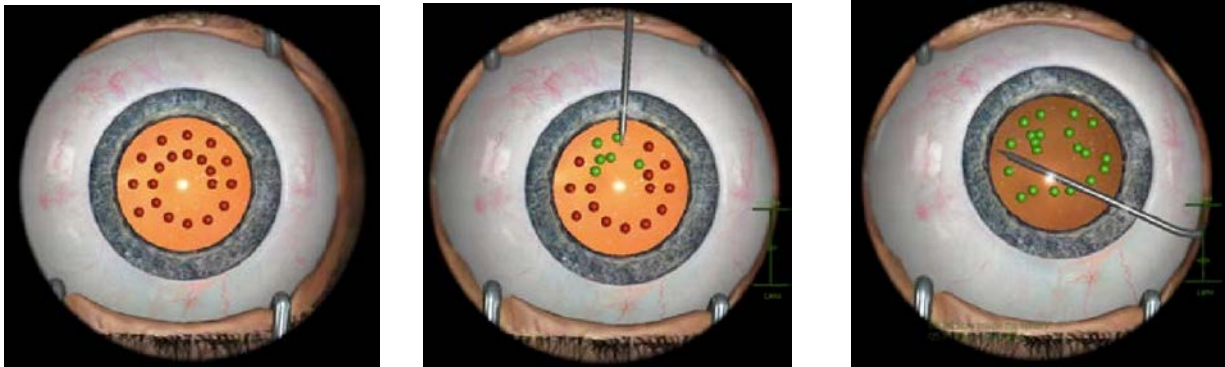
### ANTERIOR CHAMBER NAVIGATION

The following tasks will train basic hand-eye coordination in the anterior chamber. You will learn to perform efficient and controlled movements using a pointing instrument. There are two types of tasks within this module—Navigation Training and Anti-Tremor Training.

#### Cataract Navigation Training

*Learning objective:* Train your manual dexterity, improve your eye-hand coordination, and understand the dimensions of the anterior chamber by touching the tip of your instrument to each red sphere in the anterior chamber. You will complete each task after you turn all the spheres green.

*Screenshot:*



*Instruments:* Yellow port pointer

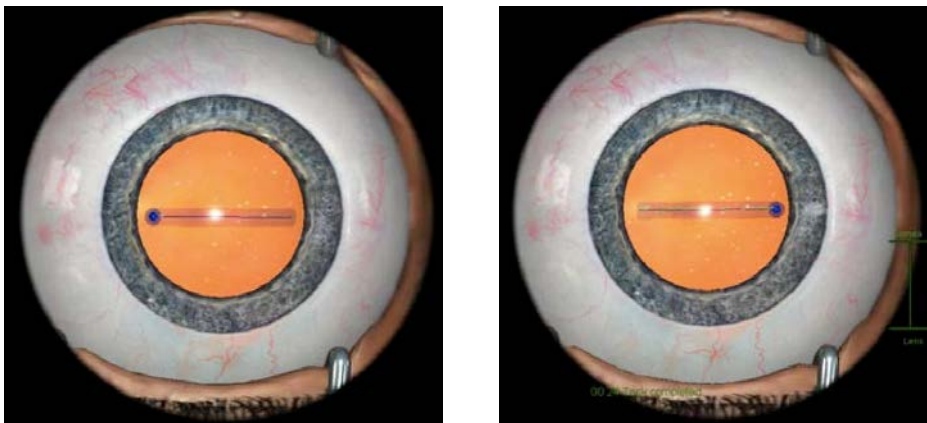
*Instructions:*

- Insert the probe into a silicon hole, keeping it oriented sideways so that the bent portion does not stick up or down
- Touch the tip of the probe to a red sphere to turn the sphere green
- Turn every sphere green
- Remove the probe

### **Cataract Anti-Tremor Training**

*Learning objective:* Train your manual dexterity, learn how to perform accurate instrument movements, and reduce tremor by moving the tip of your instrument to guide a sphere along a trajectory. You will complete each task after the actual trajectory of the instrument tip is displayed.

*Screenshot:*



*Instruments:* Yellow port pointer

*Instructions:*

- Touch the tip of the instrument to the sphere
- Guide the sphere along the given trajectory to the end point
- The sphere will turn blue when you have arrived at the end
- Remove the probe

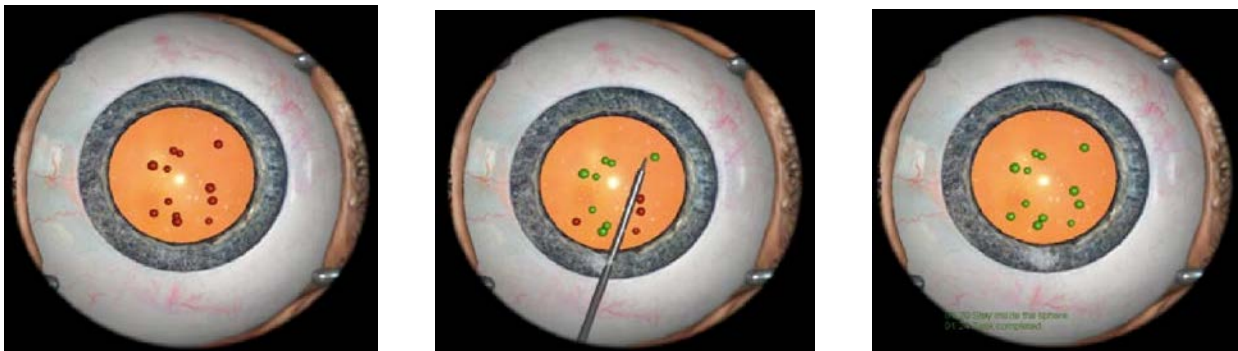
## INTRACAPSULAR NAVIGATION

The following modules use abstract tasks to train controlled movements within an empty capsule where the lens has already been removed. There are two types of tasks within this module—Navigation Training and Anti-Tremor Training:

### Navigation Training (Intracapsular)

*Learning objective:* Continue training your manual dexterity, improving your hand-eye coordination and understanding the dimensions of the capsule by touching the tip of the yellow instrument to each sphere. Unlike the previous set of navigation tasks, you will have to reach spheres within the capsular sac in this course. You will complete each task after you turn all the spheres green.

*Screenshot:*



*Instruments:* Yellow port pointer

*Instructions:*

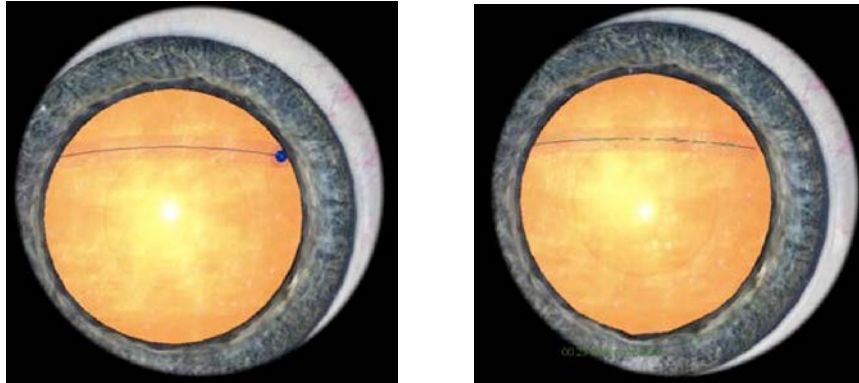
- Touch the tip of the probe to each red sphere until the sphere turns green
- Turn every sphere green
- Remove the probe
- Note: we do not have the J-shaped pointer for Intracapsular Navigation Training, Level 2

### Anti-Tremor Training (Intracapsular)

*Learning objective:* Continue training your manual dexterity, learning how to perform accurate instrument movements and getting a feeling for the dimensions

of the capsule by moving the tip of your instrument to guide a sphere along a curved trajectory. Unlike the previous set of anti-tremor tasks, these trajectories are within the capsular sac.

*Screenshot:*



*Instruments:* Red port pointer

*Instructions:*

- Touch the tip of the instrument to the sphere
- Guide the sphere along the given trajectory to the end point
- The sphere will turn blue when you arrive at the end
- Remove the probe

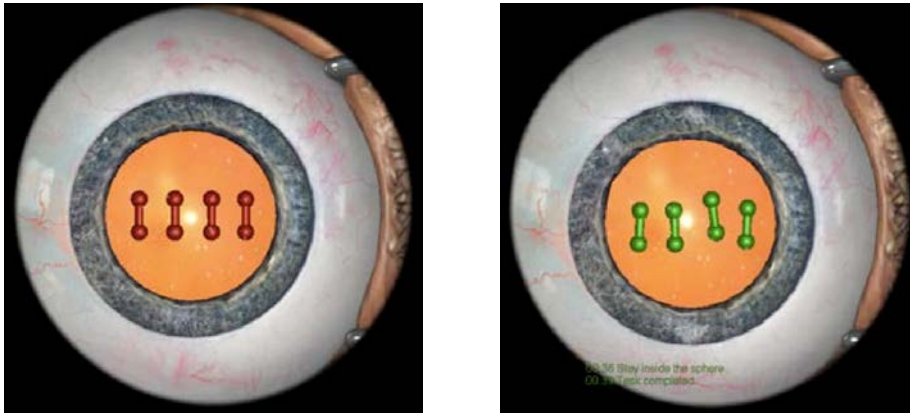
## **BIMANUAL NAVIGATION**

The following tasks will train bimanual dexterity as needed in surgical techniques such as chopping, cracking, or bimanual I/A. You will have to use two pointing instruments simultaneously to either aim at given objects or to perform opposing movements in a controlled manner. There are two types of tasks within this module—Bimanual Training and Cracking & Chopping Training:

### **Cataract Bimanual Training**

*Learning objective:* Train your manual dexterity, reduce unnecessary instrument motion, and improve your hand-eye coordination by touching two instruments, one in each hand, to two spheres simultaneously. Hold the instruments on the spheres until they change from red to green in color. You will complete each task when all the spheres are green.

*Screenshot:*



*Instruments:* Yellow and Red port pointers

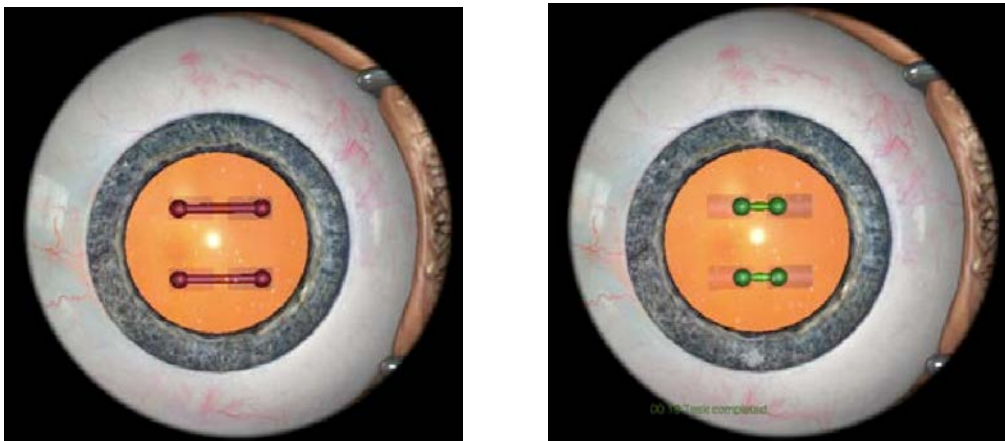
*Instructions:*

- Touch the tip of one probe to a red sphere and the tip of the other probe to the red sphere connected to the first one
- Hold the instruments steady until both spheres turn green
- Turn every pair of spheres green
- Remove both probes

### **Cataract Cracking & Chopping Training**

*Learning objective:* Prepare for cracking the lens, improve your understanding of instrument movements, and train a steady hand by using two instruments to simultaneously pierce both ends of a barbell-shaped object and moving the spheres at each end in given directions. You will complete each task when all the objects are green.

*Screenshot:*



*Instruments:* Yellow and Red port pointers

*Instructions:*

- Touch the tip of one probe to a red sphere and the tip of the other probe to the red sphere connected to the first
- Move the spheres toward each other until they turn green
- Turn both pairs of spheres green
- Remove both probes

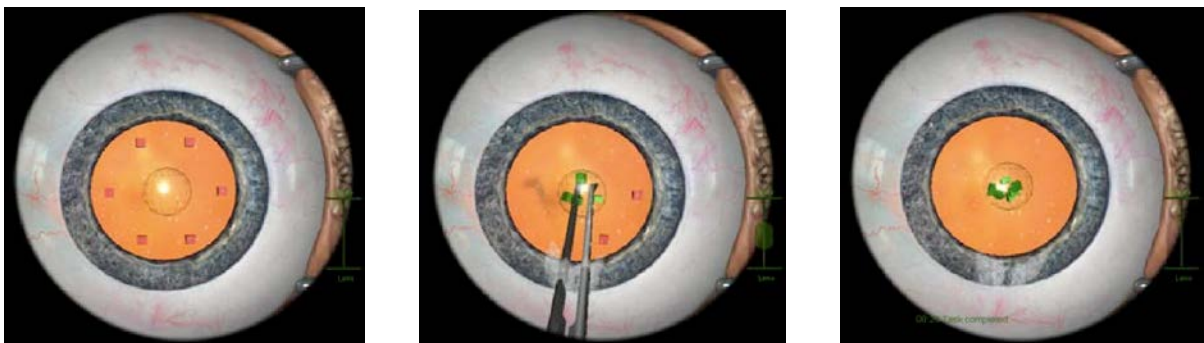
## INSTRUMENTS

The following tasks will introduce forceps and the phaco tip. You will practice handling the forceps by grasping and maneuvering abstract objects. Basic phaco skills such as irrigation, aspiration, and emulsification are trained on abstract objects. The phaco training tasks require appropriate setup of the OR machine. There are two types of tasks within this module— Forceps Training and Phaco Training:

### Cataract Forceps Training

*Learning objective:* Understand the dimensions of the anterior chamber, become familiar with forceps handling, and minimize tissue stress by using forceps to grasp objects and move them inside a wireframe sphere. You will complete each task after you move all the objects into the sphere.

*Screenshot:*



*Instruments:* Blue port forceps

*Instructions:*

- Insert the forceps sideways
- Use the forceps to pick up a red cube and move it into the central wireframe sphere. The cube will turn green once it is inside
- Continue transferring the red cubes until they are all green inside the sphere

- Turn the forceps sideways to remove them

## Phaco Training

*Learning objective:* Learn how to adjust the basic settings of the phaco machine and train your irrigation, aspiration, and phacoemulsification skills. Additionally, learn how to control eye pressure and reduce tissue stress by configuring the phaco machine while removing spheres from the anterior chamber with your phaco instrument. You will complete each task after you emulsify all the spheres.

*Screenshot:*



*Instruments:* Red port phaco instrument

*Instructions:*

- Select "Preset 1" on the "OR Machine" screen
- Step on the foot pedal until it reaches position 2 for aspiration (ASP)
- Insert your phaco handpiece into the eye
- Continue to aspirate until a sphere attaches to your tip
- Fully occlude the tip with the sphere
- Step on the foot pedal until it reaches position 3 for emulsification
- Decrease foot pedal pressure until you are back in position 2 when you have completely emulsified the sphere. You do not want to leak ultrasound energy
- Repeat aspiration and emulsification until you have emulsified all four spheres
- Remove your phaco handpiece while continuing to aspirate

## CAT-B BEGINNER

### NAVIGATION AND INSTRUMENTS

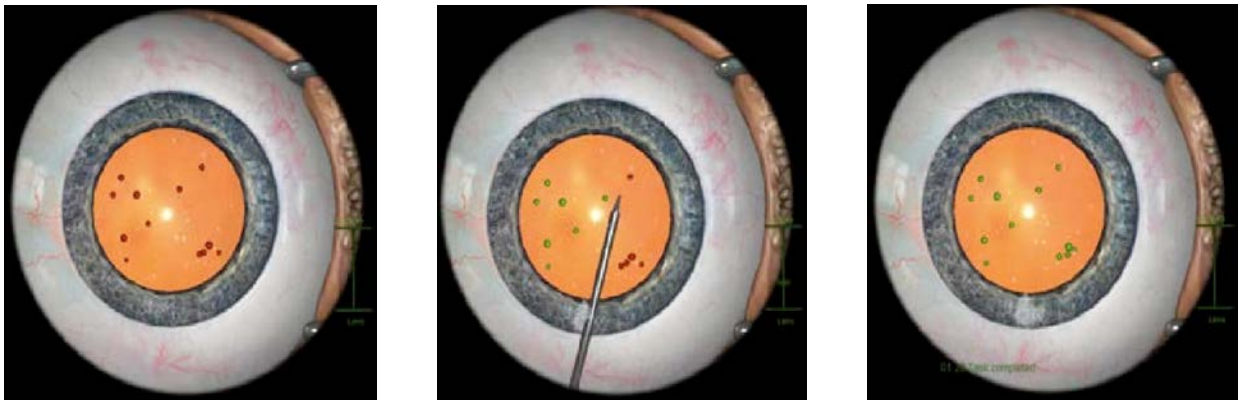
The following tasks will continue to develop your basic instrument skills. You will improve your handling of forceps and use of the phaco instrument. There are six

types of tasks within this module—Navigation Training, Anti-Tremor Training, Forceps Training, Bimanual Training, Cracking & Chopping Training, and Phaco Training.

### Cataract Navigation Training

*Learning objective:* Train your manual dexterity, improve your hand-eye coordination, and understand the dimensions of the anterior chamber by touching the tip of your probe to each sphere and holding it until each sphere turns green. Unlike previous navigation tasks, the spheres in this course vary in size and depth within the capsule.

*Screenshot:*



*Instruments:* Yellow port pointer

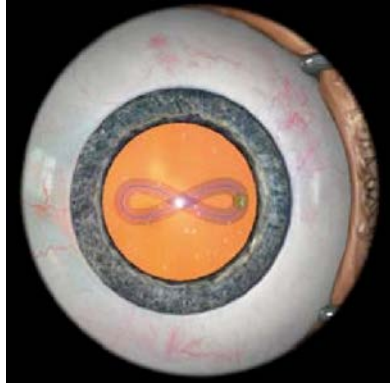
*Instructions:*

- Touch the tip of the probe to each red sphere until the sphere turns green
- Turn every sphere green
- Remove the probe

### Cataract Anti-Tremor Training

*Learning objective:* Train your manual dexterity, learn how to perform accurate instrument movements, and reduce tremor by using the tip of your instrument to move a sphere along the given trajectory. The patterns in this course are more complex than those in previous courses.

*Screenshot:*



*Instruments:* Yellow port pointer

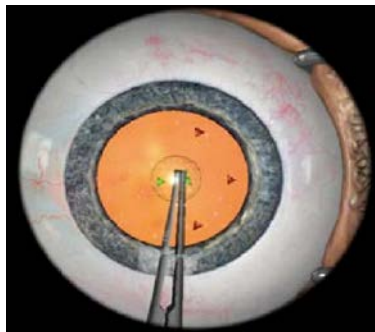
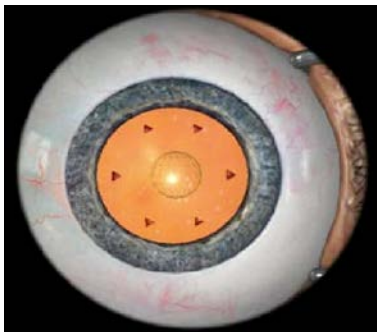
*Instructions:*

- Touch the tip of the instrument to the sphere
- Guide the sphere along the given trajectory to the end point
- The sphere will turn blue when you reach the end
- Remove the probe

### Cataract Forceps Training

*Learning objective:* Understand the dimensions of the anterior chamber, become familiar with handling forceps, and minimize tissue stress by using forceps to grasp objects and transfer them into a wireframe sphere. The objects will turn from red to green when they are in the sphere. Unlike previous forceps tasks, the objects will vary in shape and depth within the capsule. The objects are smaller and more difficult to grasp.

*Screenshot:*



*Instruments:* Blue port forceps

*Instructions:*

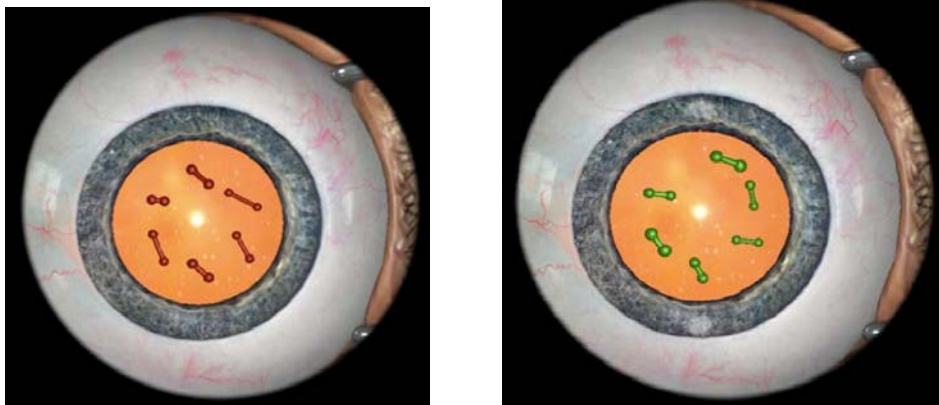
- Insert the forceps sideways

- Use the forceps to pick up a red object and move it into the central wireframe sphere. The object will turn green once it is inside
- Continue transferring the red objects until they are all green inside the sphere
- Turn the forceps sideways to remove

### Cataract Bimanual Training

*Learning objective:* Train your bimanual dexterity, reduce unnecessary instrument motion, and improve your hand-eye coordination by using two instruments to simultaneously touch two ends of a barbell-shaped object. The object will turn green. Unlike previous bimanual training tasks, the spheres of each barbell are held apart at different distances and are scattered within the anterior chamber.

*Screenshot:*



*Instruments:* Yellow and Red port pointers

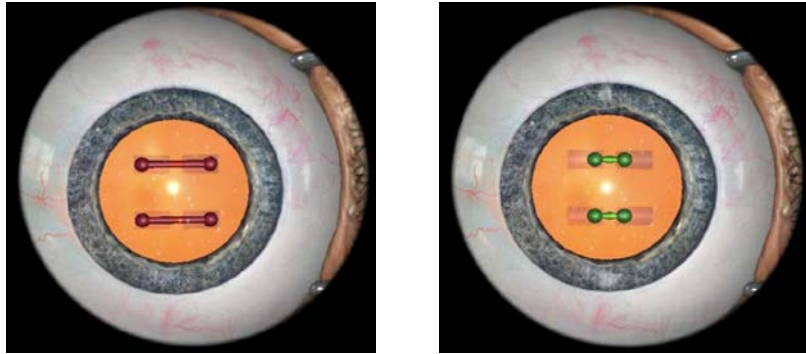
*Instructions:*

- Touch the tip of one probe to a red sphere and the tip of the other probe to the sphere connected to the first
- Hold the instruments in place until both spheres turn green
- Turn every pair of spheres green
- Remove both probes

### Cataract Cracking & Chopping Training

*Learning objective:* Prepare for cracking the lens, improve your understanding of instrument movements, and train a steady hand by using two instruments to simultaneously pierce both ends of a barbell-shaped object and move the spheres in different directions.

*Screenshot:*



*Instruments:* Yellow and Red port pointers

*Instructions:*

- Touch the tip of one probe to a red sphere and the tip of the other probe to the sphere connected to the first
- Move the spheres toward each other until they turn green
- Turn the other pair of spheres green
- Remove both probes

## Phaco Training

*Learning objective:* Learn how to adjust basic settings of the phaco machine; train irrigation, aspiration, and phacoemulsification; and learn how to control eye pressure and reduce tissue stress by configuring the phaco machine while removing spheres from the anterior chamber.

*Screenshot:*



*Instruments:* Red port phaco instrument

*Instructions:*

- Select "Preset 1" on the "OR Machine" screen
- Press the foot pedal until it reaches position 2 for aspiration (ASP)

- Insert your phaco handpiece into the eye
- Continue to aspirate until a sphere attaches to your tip
- Fully occlude the tip with the sphere
- Press the foot pedal until it reaches position 3 for emulsification
- Relax the foot pedal back to position 2 when you have completely emulsified the sphere. You do not want to leak ultrasound energy
- Repeat aspiration and emulsification steps until you have emulsified all four spheres
- Remove your phaco handpiece while continuing to aspirate

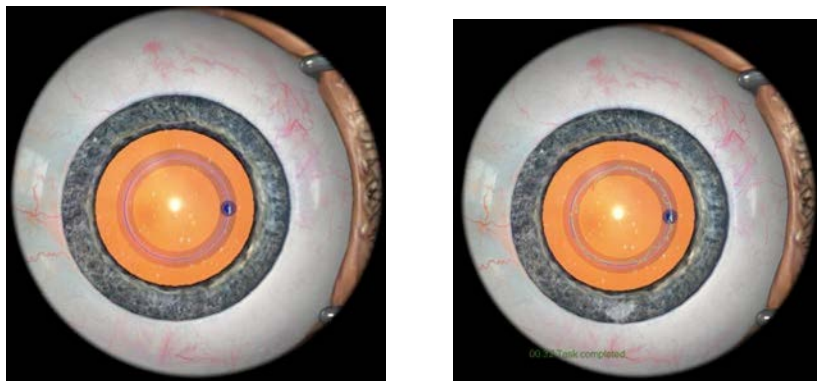
## **CAPSULORHEXIS**

The following tasks will train the circular opening of the anterior capsule. Abstract tasks will be combined with training of the surgical procedure at increasing levels of capsule tension. You will start practicing circular movements in both clockwise and counterclockwise directions and then create a corresponding rhexis. An initial tear will be offered at varying positions. The anterior chamber is permanently filled with viscoelastic so you will not have to inject viscoelastic in this course. There are two types of tasks within this module—Anti-Tremor Training and Capsulorhexis.

### **Cataract Anti-Tremor Training**

*Learning objective:* Train your manual dexterity, learn how to perform accurate instrument movements, and reduce tremor by using the tip of your instrument to move a sphere along the given trajectory.

*Screenshot:*



*Instruments:* Yellow port pointer

*Instructions:*

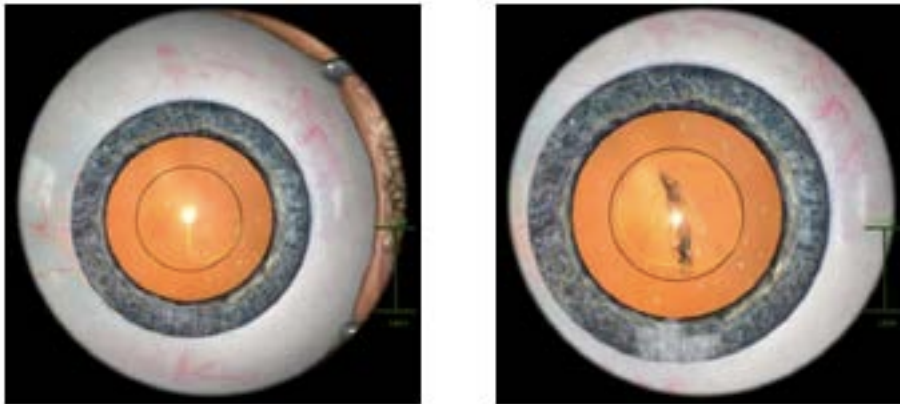
- Touch the tip of the instrument to the sphere
- Guide the sphere along the given trajectory to the end point

- The sphere will turn blue when you arrive at the end
- Remove the probe

## Capsulorhexis

*Learning objectives:* Train the rhexis techniques (shearing and ripping), refine your instrument handling for capsulorhexis, and learn how to perform a rhexis-rescue maneuver by creating a capsulorhexis

*Screenshot:*



*Instruments:* Yellow port viscoelastics cannula/cystotome (switch between the two using the “Instruments” tab) and Blue port forceps

*Instructions:* (some tasks within this course may not require all the following steps)

- Inject viscoelastic fluid into the anterior chamber using the cannula. (Press down on the foot pedal to inject.) The fluid stabilizes the anterior chamber and lessens capsule tension, thus reducing the tendency of the tear to run towards the periphery. An empty viscoelastics cannula can be replaced only once, so work economically. Remove the cannula
- Create the capsule flap using the cystotome or the forceps
- Grasp the flap with the forceps and pull it along the desired circular line. This “shearing technique” should trigger the tear to follow the tip of your instrument. If the tear begins to run outwards, switch to a “ripping technique,” in which you unfold the flap and pull it towards the center of the capsule to allow for abrupt changes in the direction of the tear. The “ripping technique” is appropriate for rescuing an errant capsulorhexis tear
- Remove the forceps or cystotome

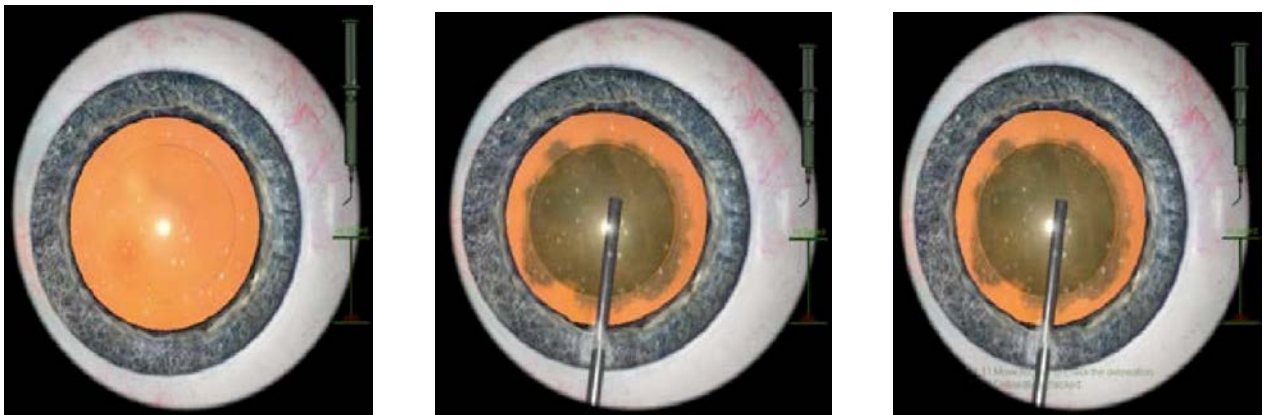
## INTRACAPSULAR TISSUE

The following tasks will introduce the essential skills of hydrodissection and delineation, as well as removal of the lens and residual cortex. The hydrodissection and delineation tasks will provide a basic understanding of instrument movements and lens interaction. In the Divide and Conquer tasks, lens parts have to be removed using the phaco instrument. The Irrigation and Aspiration tasks train the removal of residual cortex after lens removal. Different OR machine settings can be explored. There are three types of tasks within this module—Hydro Maneuvers, Phaco Divide and Conquer and Irrigation and Aspiration.

### Hydro Maneuvers

*Learning objectives:* Learn how to separate tissues from the lens, learn where to place the cannula, and become aware of the effects fluid volume and velocity have on hydro maneuvers by performing hydrodissection (separation of the lens nucleus from the cortex and the capsule) and hydrodelineation (separation of the epinucleus from the harder inner nucleus) on an eye with capsulorhexis already performed.

*Screenshot:*



*Instruments:* Yellow port dissection cannula

*Instructions:*

- Place the cannula directly under the capsule, perpendicular to the capsulorhexis edge. Use the foot pedal to inject fluid
- Complete the procedure fluently to take advantage of the fluid wave's inertia
- Check the hydrodissection by rotating the cortex
- Position the tip of the cannula about 1 mm below the capsulorhexis and use the foot pedal to inject fluid. You should see a “golden ring” evolving

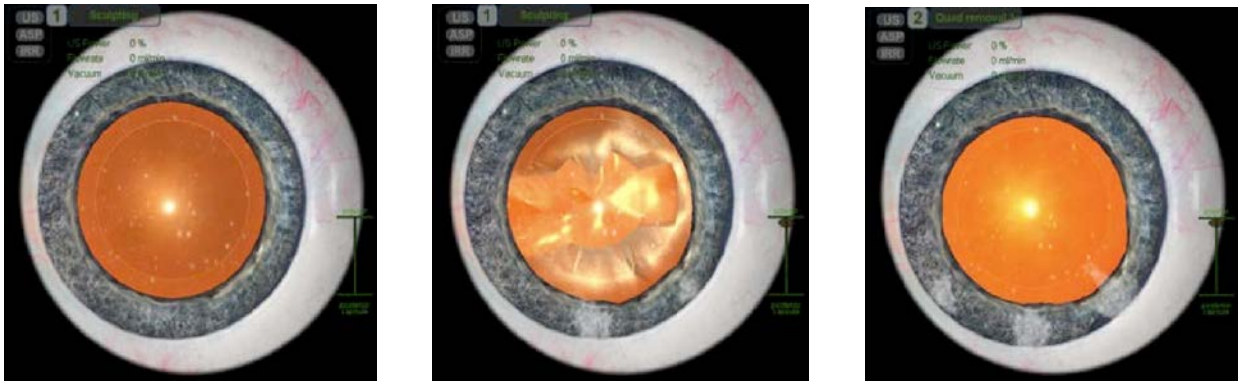
around the delineated nucleus. The radius of the delineated nucleus should be at least 60% of the lens radius

- Check the delineation by moving the nucleus in various directions. During this movement, a gap should appear between the nucleus and epinucleus
- Remove the cannula

## Phaco Divide and Conquer

*Learning objectives:* Become aware of groove depth when sculpting, train lens cracking with bimanual techniques, and learn to optimize the parameters of the phaco machine. You will complete each task when you have sculpted, cracked and emulsified the lens.

*Screenshot:*



*Instruments:* Yellow port push-pull/lens rotator/lens pusher/lens dialer (switch among the tools using the “Instruments” tab) and Red port phaco instrument/straight lens rotator

*Instructions:*

- Select “Preset 1” on the “OR Machine” screen for sculpting
- Create the grooves using the phaco tip. Deep grooves facilitate cracking but increase the risk of capsular damage
- Crack the lens into parts using two instruments to apply pressure orthogonal to the groove. Push the sides of the groove apart until the lens cracks. Be careful not to rupture the capsule.
- Select “Preset 2” on the “OR Machine” screen for emulsification
- Aspirate a lens piece carefully to move it away from vulnerable parts like the capsule and the cornea
- Make sure the phaco tip is completely occluded before moving the foot pedal to position 3 for emulsification
- Emulsify and remove all the lens parts
- Remove the phaco probe

## Irrigation and Aspiration

*Learning objectives:* Perform safe and efficient removal of cortex, practice configuration of the phaco machine, and observe how different I/A instrument types influence your technique. You will complete each task when you have successfully removed the cortex with I/A.

*Screenshot:*



*Instruments:* Yellow port aspirator/aspirator, J-shaped (switch using the “Instruments” tab) and Red port irrigator

*Instructions:*

- Select “Preset 4” in the “OR Machine” screen
- First insert your irrigator (Red port) with the foot pedal at position 1
- Insert your aspirator (Yellow port) while aspirating at a low level, foot pedal position 2
- Start aspirating the sub-anterior capsular region and maintain an occluded tip by continuously aspirating at a moderate level
- Pull the cortex away from the capsule until it is a safe distance away
- Increase your level of aspiration to start removing the cortex. Keep the aspirator opening away from the capsule to prevent capsular tear
- When you have completely removed the cortex, first pull out your aspirator. Then remove your irrigator

## STOP AND CHOP

The following tasks will teach skills used in the Stop and Chop technique for nuclear segmentation and removal. You will begin by carving a central groove into the lens using the phaco instrument and then splitting the nucleus into two halves. Subsequently, the lens halves will be aspirated with the phaco tip and subdivided with a vertical chopper. There are two types of tasks within this module—Phaco Divide and Conquer and Phaco Chopping Training:

## Phaco Divide and Conquer

*Learning objectives:* Familiarize yourself with groove depth when sculpting, practice lens cracking using bimanual techniques, and optimize the parameters of the phaco machine. You will complete each task when you have sculpted, cracked and emulsified the lens.

*Screenshot:*



*Instruments:* Yellow port push-pull/lens rotator/lens pusher/lens dialer (switch among the tools using the “Instruments” tab) and Red port phaco instrument/straight lens rotator

### *Instructions*

- Crack the lens using two instruments to apply pressure orthogonal to the groove. Push the sides of the groove apart until the lens cracks
- Select “Preset 2” on the “OR Machine” screen for emulsification
- Aspirate a lens part carefully to move it away from vulnerable structures such as the capsule and the cornea
- Make sure the phaco tip is completely occluded before moving the foot pedal to position 3 for emulsification
- Emulsify and remove all the lens parts
- Remove the phaco probe

## Phaco Chopping Training

*Learning objectives:* Train lens segmentation using the chopping technique, improve your bimanual dexterity, and avoid stress on the capsule. You will complete each task when you have aspirated and chopped the disc, creating two or four disc quarters, depending on the level.

*Screenshot:*



*Instruments:* Yellow port chopper and Red port phaco instrument

*Instructions:*

- The yellow sphere in the center of the disc represents the spot where you should aspirate the disc. If there is a whole disc, use a little ultrasound to create a small hold for better aspiration and access to the sphere; if there are segments, you can skip this step
- Aim the phaco tip at the sphere
- Aspirate the yellow sphere using a high vacuum level while keeping the phaco tip in the capsule center. The green ball turns red if your tip moves away from the original point of aspiration
- Keep the phaco tip in the capsule center while you insert the chopper
- Position the chopper at the edge of the disc under the anterior capsule
- Pull the chopper toward the disc center and along the dotted line
- Change the direction of movement of the chopper by 90 degrees when you reach the end of the dotted line. The disc should split
- Repeat steps until you have created two or four quadrants
- Remove your instruments

## **IOL INSERTION**

This module will teach the last step in cataract surgery—inserting an acrylic posterior chamber IOL into an empty capsule.

### **IOL Insertion**

*Learning objectives:* Learn how to correctly insert an IOL into the capsular bag.

*Screenshot:*



*Instruments:* Yellow port viscoelastics cannula/push-pull/spatula/aspirator (switch among the tools using the “Instruments” tab) and Red port IOL injector/coaxial I/A 45 degrees (exclusive)/irrigator

*Instructions:*

- Use the viscoelastic cannula to inject the fluid into the capsule bag
- Too much viscoelastic can rupture the capsule; watch out for the iris moving upwards as a warning sign
- Return to the instruments tab to select the IOL injector
- Position the instrument tip so the beveled side is facing down
- Insert the IOL using the instrument foot pedal. This will cause the IOL to unfold, and its two haptics will hold the IOL in place
- If the IOL is not in the correct location or orientation, use the push-pull instrument (select from instrument tab) to apply gentle force to the haptics for IOL readjustment
- Select the Coaxial I/A 45-degree instrument or the aspirator and irrigator combination for viscoelastic removal
- Apply preset 4 machine setting
- Use the instrument foot pedal to irrigate
- Enter the eye with the aspirator to remove viscoelastic fluid. Be sure to apply aspiration to the capsule periphery and underneath the IOL.

## PGY-3 COURSES: CAT-C INTERMEDIATE, CAT-D ADVANCED

CAT-C and CAT-D courses take your surgical skills to a higher level: practice advanced surgery techniques before performing multi-step cataract procedures in a simulated surgical environment.

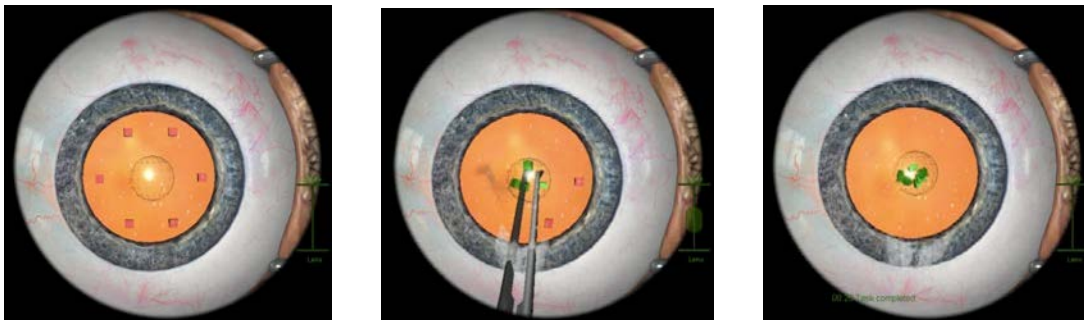
### CAPSULORHEXIS

The following tasks will enhance your basic capsulorhexis skills. Following a preparatory abstract forceps training, you will practice tearing an initial flap into the capsule. The rhexis will then be performed on capsules with increasing tension, which makes the capsule more sensitive. You will have to complete a given tissue configuration twice—once with a guiding circle and once without one. There are two types of tasks within this module—Forceps Training and Capsulorhexis.

#### Cataract Forceps Training

*Learning objectives:* Understand the dimensions of the anterior chamber, become familiar with forceps handling, and minimize tissue stress by using forceps to grasp red objects and to transfer them into a wireframe sphere. The objects will turn green when they are within the sphere. You will complete each task after you move all the objects into the sphere and they are green.

*Screenshot:*



*Instruments:* Blue port forceps

*Instructions:*

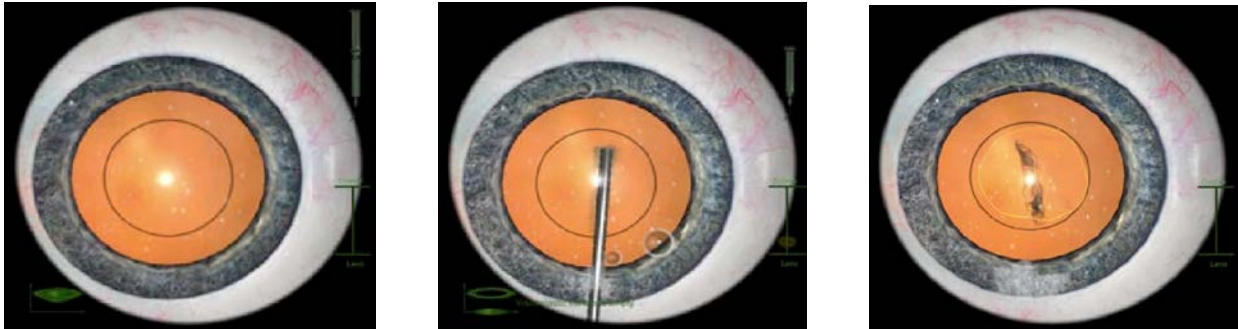
- Insert the forceps sideways
- Use the forceps to pick up a red cube and move it into the central wireframe sphere. The cube will turn green once it is inside
- Continue transferring the red cubes until they are all green inside the sphere

- Turn the forceps sideways to remove

## Capsulorhexis

*Learning objectives:* Train the rhexis techniques (shearing and ripping), refine your instrument handling for capsulorhexis, and learn how to perform a rhexis-rescue maneuver by creating a capsulorhexis. You will complete each task after you have created a capsulorhexis.

*Screenshot:*



*Instruments:* Yellow port viscoelastics cannula/cystotome (switch between the two using the “Instruments” tab) and Blue port forceps

*Instructions:* (some tasks within this course may not require all the following steps)

- Inject viscoelastic fluid into the anterior chamber using the cannula. (Press down on the foot pedal to inject.) The fluid stabilizes the anterior chamber and lessens capsule tension, thus reducing the tendency of the tear to run towards the periphery. An empty viscoelastics cannula can be replaced only once so work economically. Remove the cannula
- Create the capsule flap with the cystotome or the forceps
- Grasp the flap with the forceps and pull it along the desired circular line. This “shearing technique” should trigger the tear to follow the tip of your instrument. If the tear begins to run outwards, switch to a “ripping technique,” in which you unfold the flap and pull it towards the center of the capsule to allow for abrupt changes in the direction of the tear. The “ripping technique” is appropriate for rescuing an errant capsulorhexis tear
- Remove the forceps or cystotome

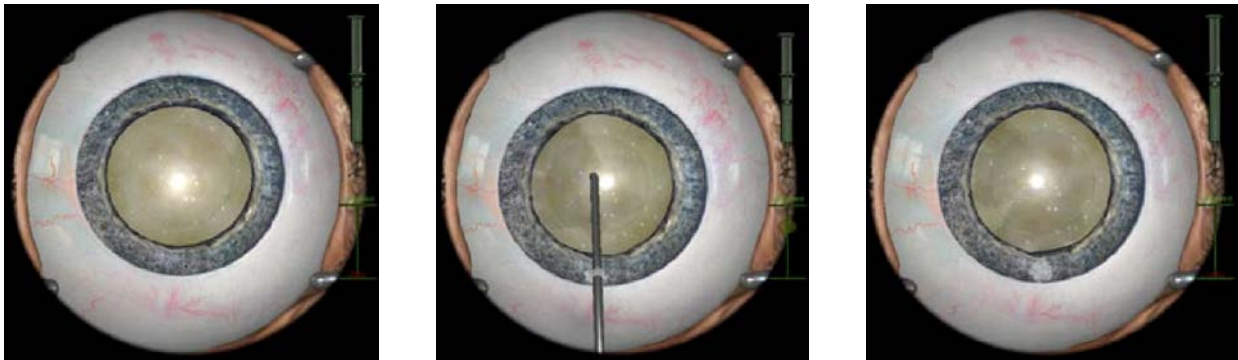
## DIVIDE AND CONQUER

The following tasks will help you develop an advanced understanding of nuclear segmentation using the divide and conquer technique. First, you will enable nuclear rotation by performing hydrodissection and hydrodelineation. After cracking a pre-sculpted lens, you will then perform the complete divide and conquer procedure. There are two types of tasks within this module— Hydro Maneuvers and Phaco Divide and Conquer:

### Hydro Maneuvers

*Learning objectives:* Learn how to separate tissues from the lens, learn where to place the cannula, and become aware of the effects fluid volume and velocity have on hydro maneuvers by performing hydrodissection and hydrodelineation on an eye with capsulorhexis already performed. You will complete each task after you perform hydrodissection and hydrodelineation.

*Screenshot:*



*Instruments:* Yellow port dissection cannula

*Instructions:*

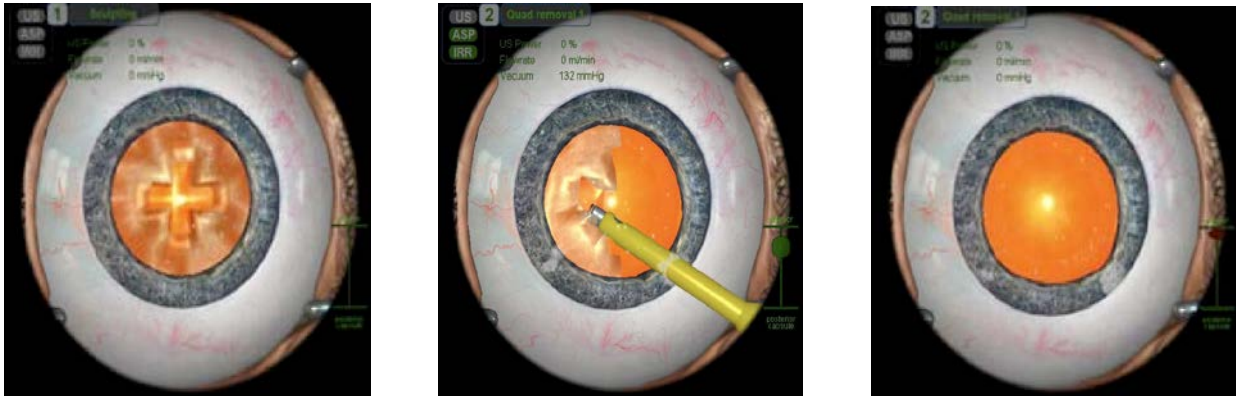
- Place the cannula directly under the capsule, perpendicular to the capsulorhexis edge. Use the foot pedal to inject fluid
- Complete the procedure fluently to take advantage of the fluid wave's inertia
- Check the hydrodissection by rotating the cortex
- Position the tip of the cannula about 1 mm below the capsulorhexis and use the foot pedal to inject fluid. Soon you should see a “golden ring” evolving around the delineated nucleus. The radius of the delineated nucleus should be at least 60% of the lens radius
- Test the delineation by moving the nucleus in various directions. During this movement, a gap should appear between nucleus and epinucleus

- Remove the cannula

## Phaco Divide and Conquer

*Learning objectives:* Familiarize yourself with groove depth while sculpting, train lens cracking with bimanual techniques, and optimize the parameters of the phaco machine.

*Screenshot:*



*Instruments:* Yellow port push-pull/lens rotator/lens pusher/lens dialer (switch among the tools using the “Instruments” tab) and Red port phaco instrument/straight lens rotator

*Instructions:*

- Crack the lens into parts using two instruments to apply pressure orthogonal to the groove. Push the sides of the groove apart until the lens cracks
- Select “Preset 2” on the “OR Machine” screen for emulsification
- Aspirate a lens part carefully to move it away from vulnerable parts like the capsule and the cornea
- Make sure the phaco tip is completely occluded before moving the foot pedal to position 3 for emulsification
- Emulsify and remove all the lens parts
- Remove the phaco probe

## CHOPPING

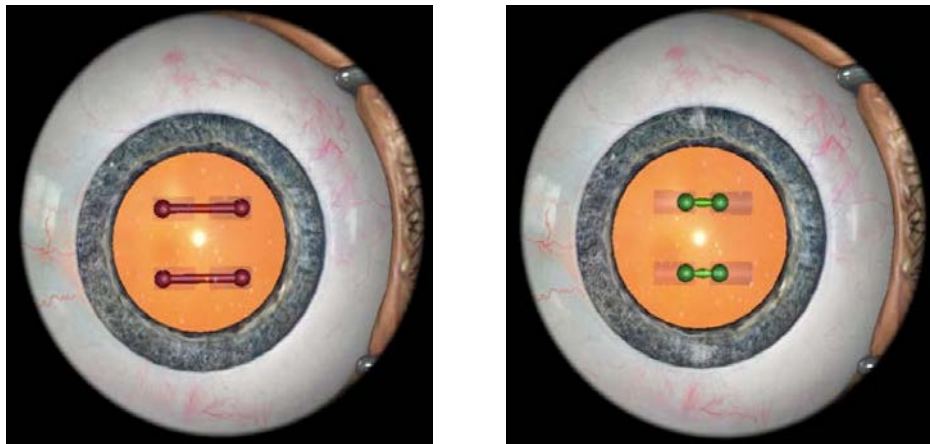
The following tasks will let you practice bimanual instrument movements and chopping techniques as needed for lens removal. In the abstract Cracking and Chopping Training tasks, you will practice the bimanual instrument movements required for lens cracking and handling lens segments. The horizontal chopping

technique will be introduced in the Chopping Training tasks; you will have to stabilize the lens with the phaco tip and at the same time chop it into smaller pieces using a vertical chopper. There are two types of tasks within this module—Cracking & Chopping Training and Phaco Chopping Training.

### **Cataract Cracking & Chopping Training**

*Learning objectives:* Prepare for cracking the lens, improve your understanding of instrument movements, and train a steady hand by using two instruments to simultaneously pierce both ends of a barbell-shaped object and moving the spheres at each end in given directions. You will complete each task when you have repeated this for all the objects, turning all of the green.

*Screenshots:*



*Instruments:* Yellow and Red port pointers

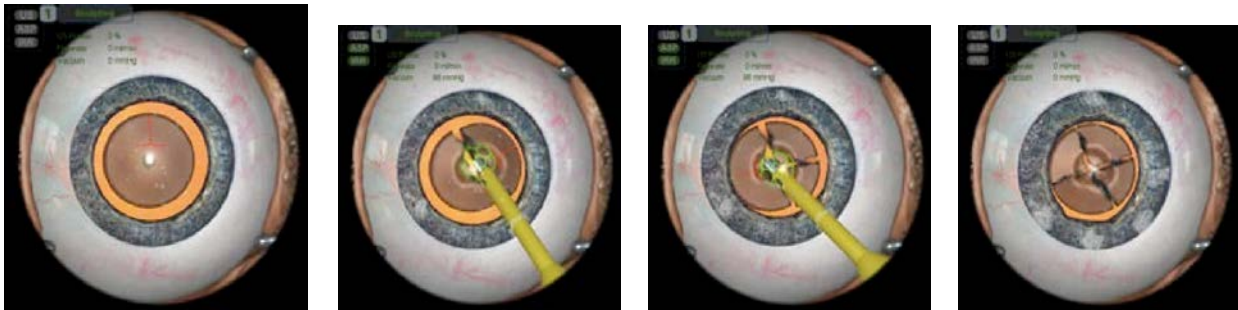
*Instructions:*

- Touch the tip of one probe to a red sphere and the tip of the other probe to the red sphere connected to the first
- Move the spheres toward each other until they turn green
- Turn both pairs of spheres green
- Remove both probes

### **Phaco Chopping Training**

*Learning objectives:* Train lens segmentation using the chopping technique, improve your bimanual dexterity, and avoid placing stress on the capsule. You will complete each task when you have aspirated and chopped the disc, creating two or four disc quarters, depending on the level.

*Screenshot:*



*Instruments:* Yellow port chopper and Red port phaco instrument

*Instructions:*

- The yellow sphere in the center of the disc represents the spot where you should aspirate the disc. If there is a whole disc, use a little ultrasound to create a small hold for better aspiration and access to the sphere; if there are segments, you can skip this step
- Aim the phaco tip at the sphere
- Aspirate the yellow sphere using a high vacuum level while keeping the phaco tip in the capsule center. The green ball turns red if your tip moves away from the original point of aspiration
- Keep the phaco tip in the capsule center while you insert the chopper
- Position the chopper at the edge of the disc under the anterior capsule
- Pull the chopper toward the disc center and along the dotted line
- Change the direction of movement of the chopper by 90 degrees when you reach the end of the dotted line. The disc should split
- Repeat steps as necessary until you have created two or four quadrants
- Remove your instruments

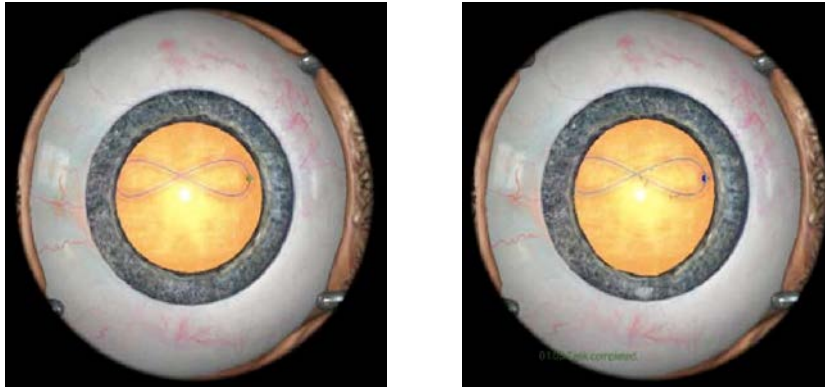
## **IRRIGATION/ASPIRATION**

The following tasks will train the removal of residual cortex while avoiding a capsular rupture caused by exerting stress to capsule and zonular fibers. The intracapsular Anti-Tremor task is intended to prepare you for capsule polishing. The following intracapsular Navigation task trains instrument handling in the subanterior capsular region, especially with J-shaped instruments. In the Irrigation and Aspiration tasks, you can explore the use of adequate vacuum and flow values for removing residual cortex. There are three types of tasks within this module—Anti-Tremor Training, Irrigation and Aspiration and Cataract Navigation Training.

### **Cataract Anti-Tremor Training**

**Learning objectives:** Train your manual dexterity, learn how to perform accurate instrument movements, and reduce tremor by using the tip of your instrument to move a sphere along the given trajectory.

**Screenshot:**



**Instruments:** Yellow port pointer

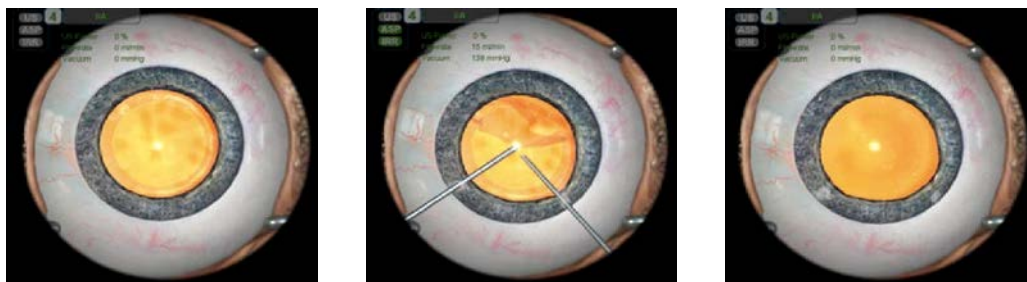
**Instructions:**

- Touch the tip of the instrument to the sphere
- Guide the sphere along the given trajectory to the end point
- The sphere will turn blue when you arrive at the end
- Remove the probe

## **Irrigation and Aspiration**

**Learning objectives:** Exercise safe and efficient removal of cortex, learn to configure the phaco machine, and determine how different I/A instrument types influence your technique. You will complete each task when you have successfully removed the cortex through I/A.

**Screenshot:**



*Instruments:* Yellow port aspirator/aspirator, J-shaped (switch using the “Instruments” tab) and Red port irrigator

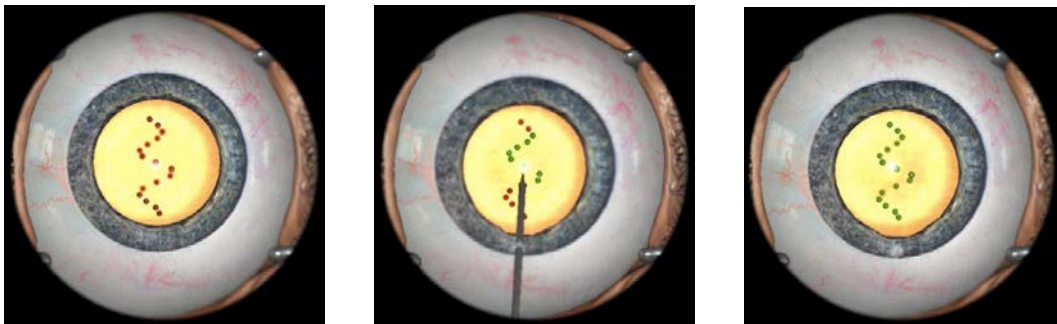
*Instructions:*

- Select “Preset 4” in the “OR Machine” screen
- First insert your irrigator (Red port) with the foot pedal at position 1
- Insert your aspirator (Yellow port) while aspirating at a low level, foot pedal position 2
- Start aspirating the sub-anterior capsular region and maintain an occluded tip by continuously aspirating at a moderate level
- Pull the cortex away from the capsule until it is a safe distance away
- Increase your level of aspiration to start removing the cortex. Keep the aspirator opening away from the capsule to help prevent capsular tear
- When you have completely removed the cortex, first pull out your aspirator. Then, remove your irrigator

### Cataract Navigation Training

*Learning objectives:* Train your manual dexterity, improve your hand-eye coordination, and understand the dimensions of the anterior chamber by touching the tip of your probe to each sphere and holding it there until each sphere turns green. Unlike previous navigation tasks, the spheres in this course vary in size and depth within the capsule. You will complete each task after you turn every sphere green.

*Screenshot:*



*Instruments:* Yellow port pointer

*Instructions:*

- Touch the tip of the probe to each red sphere until the sphere turns green
- Turn every sphere green
- Remove the probe

**You are now ready for CAT-D.**

CAT-D courses offer training of the capsulorhexis under more demanding and varying conditions, such as increasing capsule tensions or weak zonules. Be prepared for complications.

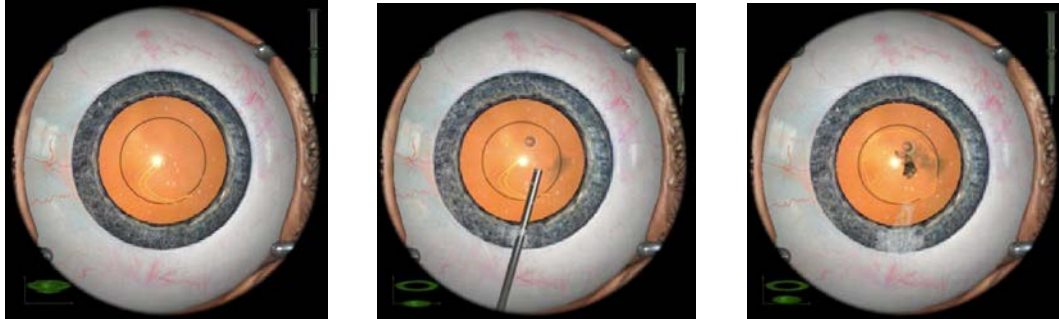
### **CAPSULORHEXIS ERRANT TEAR**

The following tasks will test your technique of creating a clockwise or counterclockwise rhexis under increasingly difficult conditions; the capsule tension is medium to high, and the tear tends to run outwards. In all tasks, viscoelastic must be injected before opening the anterior capsule. An initial tear has been created and a guiding circle is displayed.

#### **Capsulorhexis**

*Learning objectives:* Train the rhexis techniques (shearing and ripping), refine instrument handling for capsulorhexis, and learn how to perform a rhexis-rescue maneuver by creating a capsulorhexis. You will complete each task after you have created a capsulorhexis.

*Screenshot:*



*Instruments:* Yellow port viscoelastics cannula/cystotome (switch between the two using the “Instruments” tab) and Blue port forceps

*Instructions:* (some tasks within this course may not require all the following steps)

- Inject viscoelastic fluid into the anterior chamber using the cannula. (Press down on the foot pedal to inject.) The fluid stabilizes the anterior chamber and lessens capsule tension, thus reducing the tendency of the tear to run towards the periphery. An empty viscoelastics cannula can be replaced only once so work economically. Remove the cannula

- Create the capsule flap using the cystotome or the forceps
- Grasp the flap with the forceps and pull it along the desired circular line. This “shearing technique” should trigger the tear to follow the tip of your instrument. If the tear begins to run outwards, switch to a “ripping technique,” in which you unfold the flap and pull it towards the center of the capsule to allow for abrupt changes in the direction of the tear. The “ripping technique” is appropriate for rescuing an errant capsulorhexis tear
- Remove the forceps or cystotome

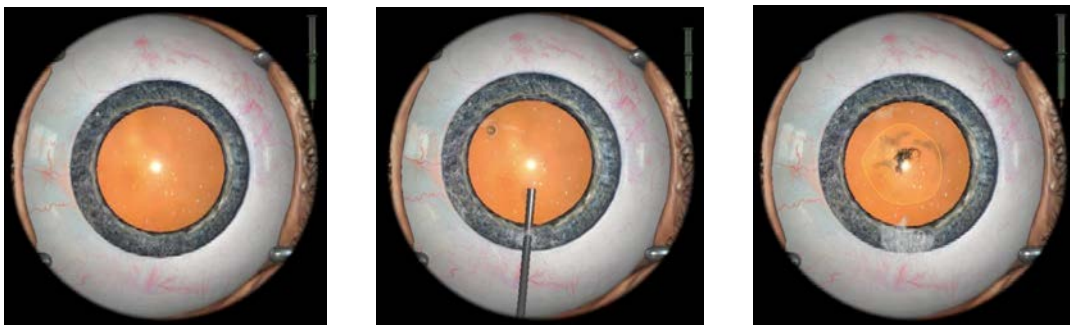
## WEAK ZONULES AND CAPSULES

In the following tasks, you will have to perform a capsulorhexis on a patient with weak zonules, which cause the lens to get loose, making the surgical procedure more demanding. Between the tasks, capsular tension varies from low to high. In some tasks, an initial tear has to be created; and in some tasks, the tear tends to run outwards. Throughout the course, viscoelastic needs to be injected and no guiding circle is displayed. Finally, hydrodissection and delineation with a weak capsule, as well as irrigation and aspiration with weak zonules, are trained. There are three types of tasks within this module— Capsulorhexis, Hydro Maneuvers and Irrigation and Aspiration.

### Capsulorhexis

*Learning objectives:* Train the rhexis techniques (shearing and ripping), refine your instrument handling for capsulorhexis, and learn how to perform a rhexis-rescue maneuver by creating a capsulorhexis. You will complete each task after you have created a capsulorhexis.

*Screenshot:*



*Instruments:* Yellow port viscoelastics cannula/cystotome (switch between the two using the “Instruments” tab) and Blue port forceps

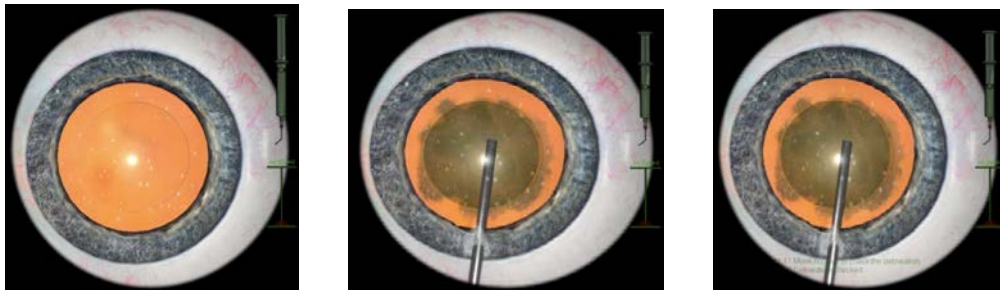
*Instructions:* (some tasks within this course may not require all the following steps)

- Inject viscoelastic fluid into the anterior chamber using the cannula. (Press down on the foot pedal to inject.) The fluid stabilizes the anterior chamber and lessens capsule tension, thus reducing the tendency of the tear to run towards the periphery. An empty viscoelastic cannula can be replaced only once so work economically. Remove the cannula
- Create the capsule flap using the cystotome or the forceps
- Grasp the flap with the forceps and pull it along the desired circular line. This “shearing technique” should trigger the tear to follow the tip of your instrument. If the tear begins to run outwards, switch to a “ripping technique,” in which you unfold the flap and pull it towards the center of the capsule to allow for abrupt changes in the direction of the tear. The “ripping technique” is appropriate for rescuing an errant capsulorhexis tear
- Remove the forceps or cystotome

## Hydro Maneuvers

*Learning objectives:* Learn how to separate tissues from the lens, learn where to place the cannula, and familiarize yourself with the effects that fluid volume and velocity have on hydro maneuvers by performing hydrodissection and hydrodelineation on an eye with capsulorhexis already performed. You will complete each task after you perform hydrodissection and hydrodelineation.

*Screenshot:*



*Instruments:* Yellow port dissection cannula

*Instructions:*

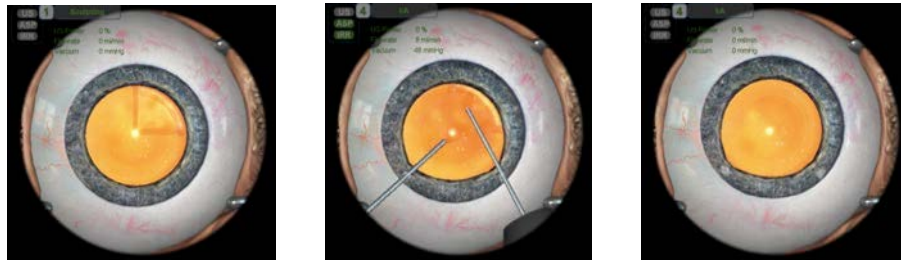
- Place the cannula directly under the capsule, perpendicular to the capsulorhexis edge. Use the foot pedal to inject fluid
- Complete the procedure fluently to take advantage of the fluid wave's inertia
- Check the hydrodissection by rotating the cortex

- Position the tip of the cannula about 1 mm below the capsulorhexis and use the foot pedal to inject fluid. Soon you should see a “golden ring” evolving around the delineated nucleus. The radius of the delineated nucleus should be at least 60% of the lens radius
- Check the delineation by moving the nucleus in various directions. During this movement, a gap should appear between the nucleus and epinucleus
- Remove the cannula

## Irrigation and Aspiration

*Learning objectives:* Perform safe and efficient removal of cortex, learn to configure the phaco machine and control the aspiration for occlusion and removal, and determine how different I/A instrument types influence your technique. You will complete each task when you have successfully removed the cortex through I/A.

*Screenshot:*



*Instruments:* Yellow port aspirator/aspirator, J-shaped (switch using the “Instruments” tab) and Red port irrigator

*Instructions:*

- Select “Preset 4” in the “OR Machine” screen
- First insert your irrigator (Red port) with the foot pedal at position 1
- Insert your aspirator (Yellow port) while aspirating at a low level, foot pedal position 2
- Start aspirating the sub-anterior capsular region and maintain an occluded tip by continuously aspirating at a moderate level
- Pull the cortex away from the capsule until it is a safe distance away
- Increase your level of aspiration to start removing the cortex. Keep the aspirator opening away from the capsule to help prevent capsular tear
- When you have completely removed the cortex, first pull out your aspirator. Then, remove your irrigator

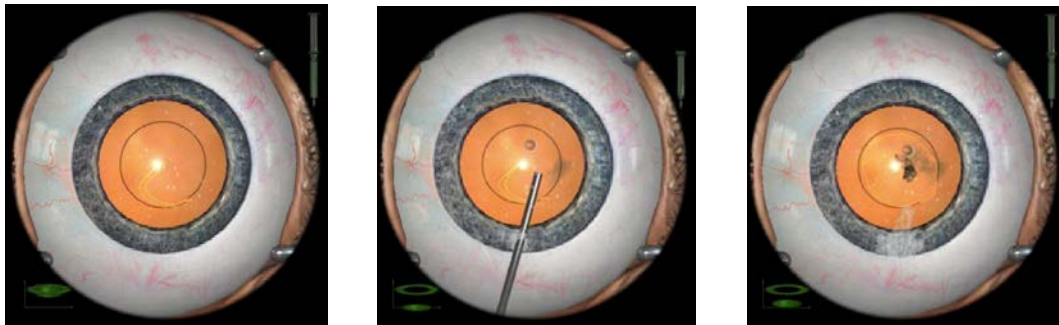
## CAPSULORHEXIS VARIATIONS

The following tasks are the most difficult of all capsulorhexis courses because the conditions under which the rhexis has to be created vary randomly and unpredictably. For example, capsular tension may be low, medium or high; or the zonules might be intact or weak. The aim of this course is to prepare you for different patient cases and to further improve your skills.

### Capsulorhexis

*Learning objectives:* Train the rhexis techniques (shearing and ripping), refine your instrument handling for capsulorhexis, and learn how to perform a rhexis-rescue maneuver by creating a capsulorhexis. You will complete each task after you have created a capsulorhexis.

*Screenshot:*



*Instruments:* Yellow port viscoelastics cannula/cystotome (switch between the two using the “Instruments” tab) and Blue port forceps

*Instructions:* (some tasks within this course may not require all the following steps)

- Inject viscoelastic fluid into the anterior chamber using the cannula. (Press down on the foot pedal to inject.) The fluid stabilizes the anterior chamber and lessens capsule tension, thus reducing the tendency of the tear to run towards the periphery. An empty viscoelastics cannula can be replaced only once so work economically. Remove the cannula
- Create the capsule flap using the cystotome or the forceps
- Grasp the flap with the forceps and pull it along the desired circular line. This “shearing technique” should trigger the tear to follow the tip of your instrument. If the tear begins to run outwards, switch to a “ripping technique,” in which you unfold the flap and pull it towards the center of the capsule to allow for abrupt changes in the direction of the tear. The “ripping technique” is appropriate for rescuing an errant capsulorhexis tear

- Remove the forceps or cystotome

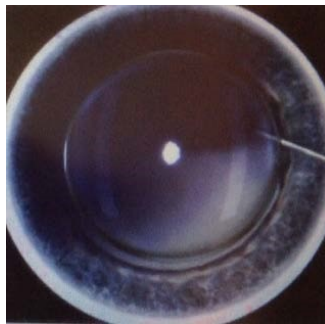
## WHITE CATARACTS

The following tasks are designed to teach you the removal of very dense, white cataracts. This requires the use of Trypan blue dye to stain the capsule for the rhexis. You will learn to take extra precaution against capsule tear when opening the bag (Argentinian flag sign) by using viscoelastic to counteract high intracapsular pressure. The aim of this course is to teach you the techniques and caution required in the removal of white cataracts. There are two types of task within this module—Capsulorhexis and Hydro Maneuvers.

### Capsulorhexis

*Learning objectives:* Stain the capsule for better visibility during the rhexis procedure, perform the rhexis, and practice hydro maneuvers on a white lens.

*Screenshot:*



*Instruments:* Yellow port air cannula/Trypan blue cannula/BSS cannula/viscoelastics cannula/cystotome/cystotome (small) (switch between the two using the “Instruments” tab), Blue port CR forceps, and Red port cystotome (straight)

*Instructions:* (some tasks within this course may not require all the following steps)

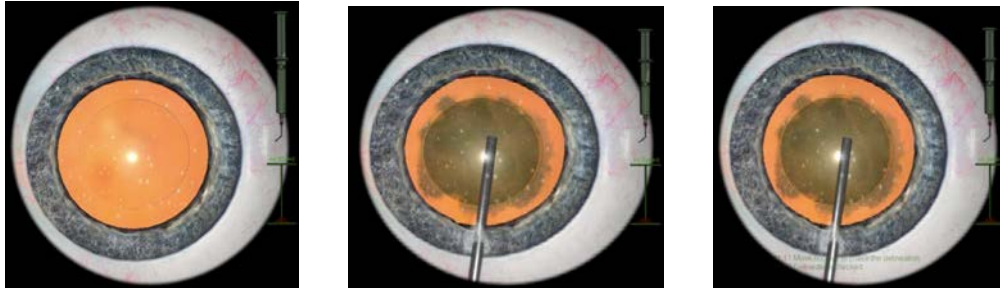
- Inject air into the anterior chamber with the air cannula to prevent dye from staining the cornea
- Inject Trypan blue dye to stain the capsule without displacing air
- Inject BSS to remove the dye and air
- Inject viscoelastic fluid into the anterior chamber using the cannula. (Press down on the foot pedal to inject.) The fluid stabilizes the anterior chamber and lessens capsule tension, thus reducing the tendency of the tear to run towards the periphery. An empty viscoelastics cannula can be replaced only once so work economically. Remove the cannula

- Create the capsule flap using the cystotome or the forceps
- Grasp the flap with the forceps and pull it along the desired circular line. This “shearing technique” should trigger the tear to follow the tip of your instrument. If the tear begins to run outwards, switch to a “ripping technique.”
- Remove the forceps or cystotome

## Hydro Maneuvers

*Learning objectives:* Learn how to separate tissues from the lens, learn where to place the cannula, and become aware of the effects that fluid volume and velocity have on hydro maneuvers by performing hydrodissection and hydrodelineation on an eye with capsulorhexis already performed. You will complete each task after you perform hydrodissection and hydrodelineation.

*Screenshot:*



*Instruments:* Yellow port dissection cannula

*Instructions:*

- Place the cannula directly under the capsule, perpendicular to the capsulorhexis edge. Use the foot pedal to inject fluid
- Complete the procedure fluently to take advantage of the fluid wave
- Check the hydrodissection by rotating the cortex
- Position the tip of the cannula about 1 mm below the capsulorhexis and use the foot pedal to inject fluid. Soon you should see a “golden ring” evolving around the delineated nucleus. The radius of the delineated nucleus should be at least 60% of the lens radius
- Check the delineation by moving the nucleus in various directions. During this movement, a gap should appear between the nucleus and epinucleus
- Remove the cannula

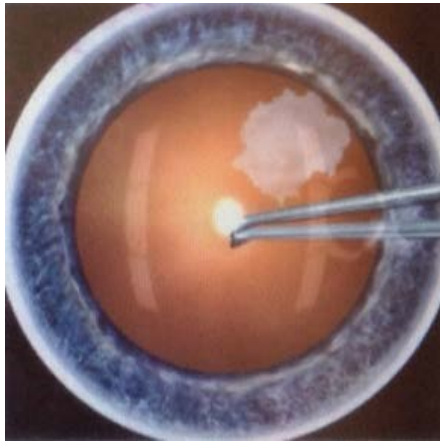
## CAPSULAR PLAQUES

The following tasks prepare you for capsulorhexis in the setting of anterior capsule plaques. Depending on the size and location of the plaque, you may create the rhexis around the plaque or through it. The latter requires great care, especially in the setting of high capsular tension and weak zonules. The aim of this course is to teach you to create capsulorhexis of anterior capsules with plaques.

### Capsulorhexis

*Learning objectives:* Train the rhexis techniques (shearing and ripping), refine your instrument handling for capsulorhexis, and learn how to perform a rhexis-rescue maneuver by creating a capsulorhexis.

*Screenshot:*



*Instruments:* Yellow port viscoelastics cannula/cystotome (switch between the two using the “Instruments” tab) and Blue port forceps

*Instructions:* (some tasks within this course may not require all the following steps)

- Inject viscoelastic fluid into the anterior chamber using the cannula. (Press down on the foot pedal to inject.) The fluid stabilizes the anterior chamber and lessens capsule tension, thus reducing the tendency of the tear to run towards the periphery. An empty viscoelastics cannula can be replaced only once so work economically.
- Remove the cannula
- Create the capsular flap using the cystotome or the forceps

- Depending on the location of the plaque, tear around it or through to achieve a circular rhexis. If tearing through the plaque, be wary of altered tissue behavior
- Grasp the flap with the forceps and pull it along the desired circular line. This “shearing technique” should trigger the tear to follow the tip of your instrument. If the tear begins to run outwards, switch to a “ripping technique.”
- Remove the forceps or cystotome

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## APPENDIX

| Learning Objective                                                                              | Module                      | Time (Hours) | Pages In Manual |
|-------------------------------------------------------------------------------------------------|-----------------------------|--------------|-----------------|
| Develop basic hand-eye coordination                                                             | ANTERIOR CHAMBER NAVIGATION | 1.5          | 27-28           |
| Learn to control movements within an empty capsule                                              | INTRACAPSULAR NAVIGATION    | 1.5          | 28-29           |
| Develop dexterity and coordination during simultaneous hand movements                           | BIMANUAL NAVIGATION         | 1.75         | 29-31           |
| Learn to use forceps and basic phaco skills                                                     | INSTRUMENTS                 | 1.5          | 31-32           |
| Reinforce basic instrument skills                                                               | NAVIGATION AND INSTRUMENTS  | 1.75         | 32-36           |
| Learn to create a circular opening in the anterior capsule                                      | CAPSULORHEXIS               | 1.75         | 36-38           |
| Learn the basics of: hydro maneuvers, phaco divide & conquer, and irrigation & aspiration       | INTRACAPSULAR TISSUE        | 1.5          | 38-41           |
| Learn the basics of lens removal                                                                | STOP AND CHOP               | 1.0          | 41-42           |
| Learn to insert an IOL                                                                          | IOL INSERTION               | 1.0          | 43-44           |
| Reinforce basic capsulorhexis skills                                                            | CAPSULORHEXIS (CAT-C)       | 1.75         | 44-45           |
| Develop an advanced understanding of divide & conquer                                           | DIVIDE AND CONQUER          | 1.25         | 45-47           |
| Develop an advanced understanding of cracking & chopping                                        | CHOPPING                    | 1.75         | 47-49           |
| Develop an advanced understanding of irrigation & aspiration                                    | IRRIGATION & ASPIRATION     | 1.0          | 49-51           |
| Learn to perform capsulorhexis in difficult cases                                               | CAPSULORHEXIS ERRANT TEAR   | 1.5          | 52-53           |
| Learn to perform capsulorhexis, hydro maneuvers, and irrigation & aspiration in difficult cases | WEAK ZONULES AND CAPSULES   | 1.75         | 53-55           |

|                                                                        |                          |     |       |
|------------------------------------------------------------------------|--------------------------|-----|-------|
| Complete advanced VR training of capsulorhexis in very difficult cases | CAPSULORHEXIS VARIATIONS | 1.0 | 55-56 |
| Review steps and precautions needed when dealing with white cataracts  | WHITE CATARACTS          | 1.0 | 56-58 |
| Review challenges of capsulorhexis with anterior capsule plaques       | CAPSULAR PLAQUES         | 1.0 | 58-59 |