Cataract Coach, Uday Devgan's YouTube Channel

Key Lessons for Residency

Basic Foundational Notes to Operate Phacoemulsification

https://cataractcoach.com/

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"In these slides you will learn:

not a thing, but don't worry. There is plenty to come. Here is your chance to turn a few slides, take a deep breath or two, and get yourself settled and ready to roll. Relax. Pour some tea. Begin."

1. Title: **Learning Grid for Cataract Surgery**

Learning Grid of Cataract Surgery Steps

Uday Devgan MD, Chief of Ophthalmology, Olive View UCLA Medical Center

1 = only basic understanding
2 = fair / still learning
3 = good / making progress
4 = excellent technique

step of surgery		medical student	PGY-2 1st block	PGY-2 2nd block	PGY-3	PGY-4 1st block	PGY-4 2nd block
consent for surgery		2	3	4	4	4	4
accurate biometry		1	2	3	4	4	4
unusual IOL calcs		1	2	3	4	4	4
retrobulbar block		1	2	3	4	4	4
draping & prepping		2	2	3	4	4	4
set-up machines		1	1	2	3	4	4
keep eye in primary position		1	1	2	3	4	4
pivot within incisions		1	1	2	3	4	4
make incisions		1	1	2	3	4	4
capsulorrhexis		1	1	1	2	3	4
hydro-dissection		1	1	1	2	3	4
basics of phaco fluidics / power		1	1	2	3	4	4
	divide & conquer	1	1	2	3	4	4
	stop & chop	1	1	1	2	3	4
	variations of chop	1	1	1	1	2	3
	flip / flip & chop	1	1	1	1	2	3
cortex removal / I&A		1	1	1	2	3	4
IOL loading into injector		1	1	2	3	4	4
IOL insertion into bag		1	1	2	3	4	4
remove viscoelastic		1	1	2	3	4	4
seal incisions & suturing		1	2	3	4	4	4
medicate & patch eye		2	2	3	4	4	4
post-op follow-up & instructions		2	2	3	4	4	4

2. Title: **Technique for Retrobulbar Anesthetic Injection**

For beginning surgeons, giving a retrobulbar injection of anesthetic is a good way to achieve both anesthesia and akinesia.

For experienced cataract surgeons, using a combination of topical anesthesia and intra-cameral anesthesia tends to work the best. **I favor topical tetracaine eye drops combined with preservative-free dilute (1% or less) lidocaine given in the anterior chamber**.

The agents used are typically lidocaine 1% (Xylocaine), bupivacaine 0.75%(Marcaine), or a combination of the two. Lidocaine tends to start working faster and lasts for a shorter period of time compared to bupivacaine which can last for many hours more. The anesthetic is drawn into a **5 or 10-cc syringe** and an **Atkinson retrobulbar needle** is used. This needle is **25 gauge** but has less of a bevel and is not as sharp as a traditional 25 g needle. The idea is that it may be less likely to inadvertently penetrate the globe.

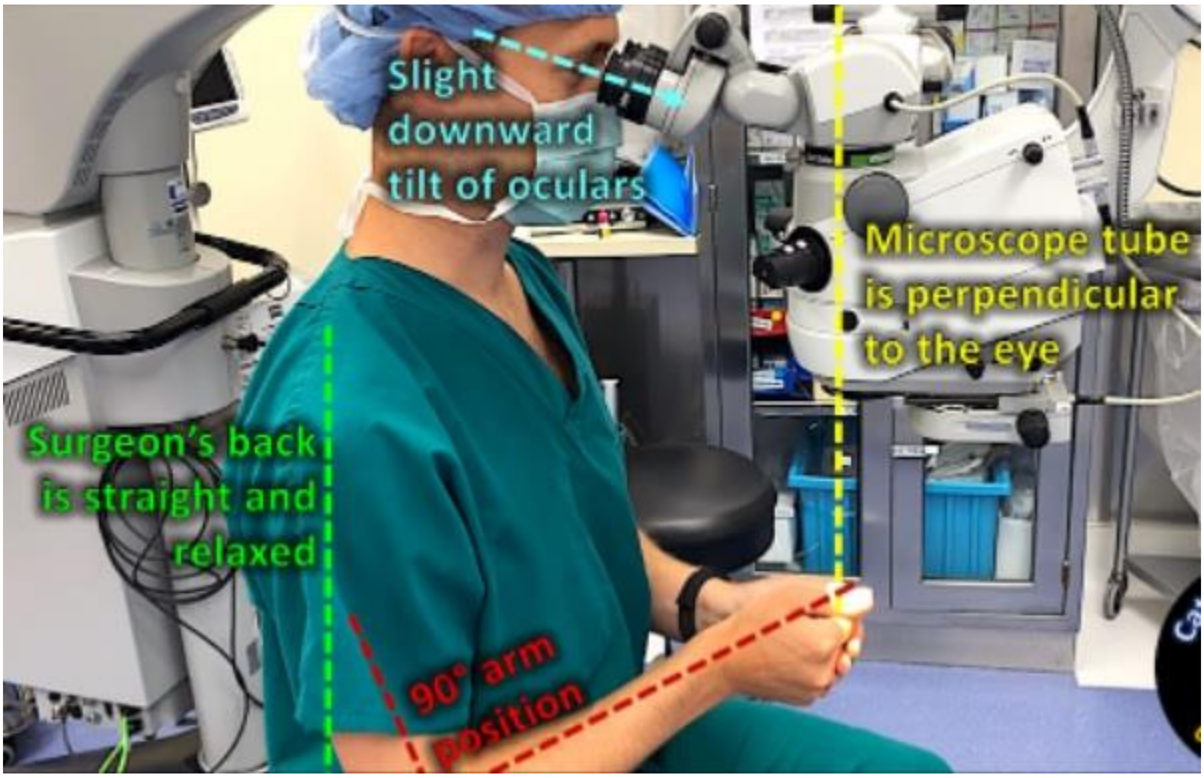
The injection **should start at the inferolateral quadrant** with care taken to avoid the lateral rectus, inferior rectus, and inferior oblique muscles. Avoid puncturing the eyelid skin close to the lid margin since there are often vessels here that tend to bleed.

The needle needs to go through the skin and then **the orbital septum (the first pop that is felt)**, then through the orbit and into **the muscle cone (the second pop that is felt)**, with the tip finally entering the **intra-conal space**. At this point, pull back slightly on the plunger to confirm that the needle is not in a vessel. Then inject about **3 or 4 cc of anesthetic** into the muscle cone. Avoid injecting a large volume of anesthetic due to the limited volume of the orbit (about 30 ccc in most adults). A huge volume of injection (8 to 10 cc) will cause pressure behind the globe and this will cause difficulties during cataract surgery.

A helpful technique is to use the fingertip or the cap of the needle to depress the lower eyelid and expose the inferior equator of the globe creating a gap by pushing the globe to the side. Once the equator is seen, it is a **straight and short** path for the needle to enter the intra-conal space.

As the anesthetic liquid is injected, the globe will come forwards and become a bit proptotic. After the injection is complete, the globe can be massaged to disperse the anesthetic bolus, reduce the retro-bulbar pressure, and resolve the proptosis. This can be confirmed by checking the globe's resistance to retropulsion, which should be about the same as the untouched other eye once the anesthetic bolus is spread evenly.

3. Title: **Surgeon Ergonomics for Ocular Surgery**



4. Title: **Draping the Eye for Cataract Surgery**

Why draping? The eyelid margin and eyelashes are often the sources of bacteria in the rare cases of endophthalmitis and the glands can create an oily coating on the cornea which impedes the surgeon's view.

- 2 possible techniques, you can check them out: https://cataractcoach.com/2019/12/15/draping-the-eye-for-cataract-surgery/

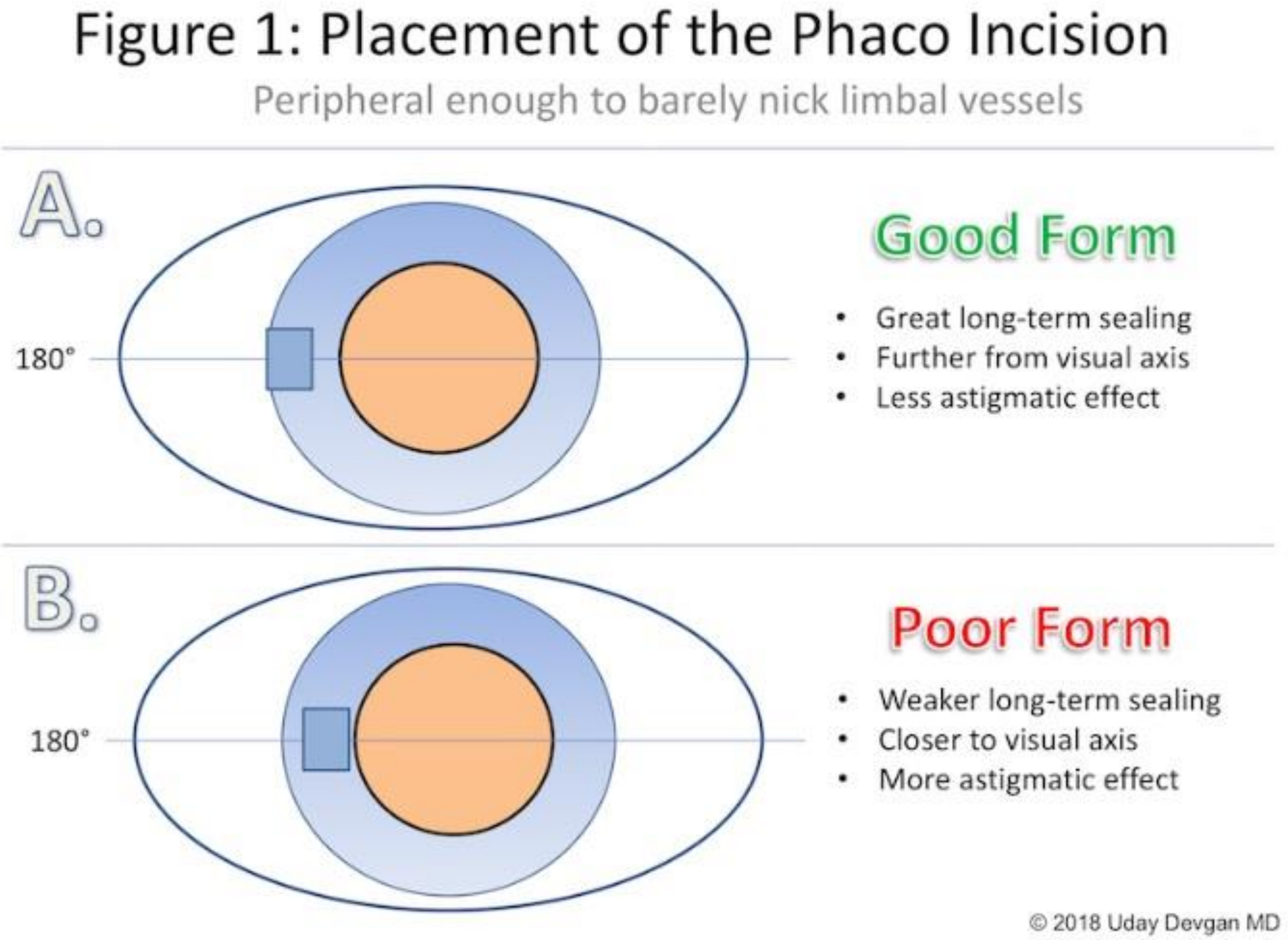
5. Title: **3 Rules for Making Phaco Incisions**

Why did cataract surgery shift from scleral incisions into corneal incisions?

Most surgeons use a corneal incision during cataract surgery because it allows less anesthesia, faster recovery, enhanced access to the anterior chamber, and excellent visual outcomes.

- **Rule 1: Stay peripheral**

The best corneal phaco incisions are the ones that **barely nick the limbal blood vessels**. This is because they are peripheral, far from the visual axis, and produce a less astigmatic effect. In addition, the vascular nature allows for more secure and better long-term sealing. A completely avascular corneal incision only heals to a small fraction of its original strength and can be opened even years later with relatively blunt instruments.

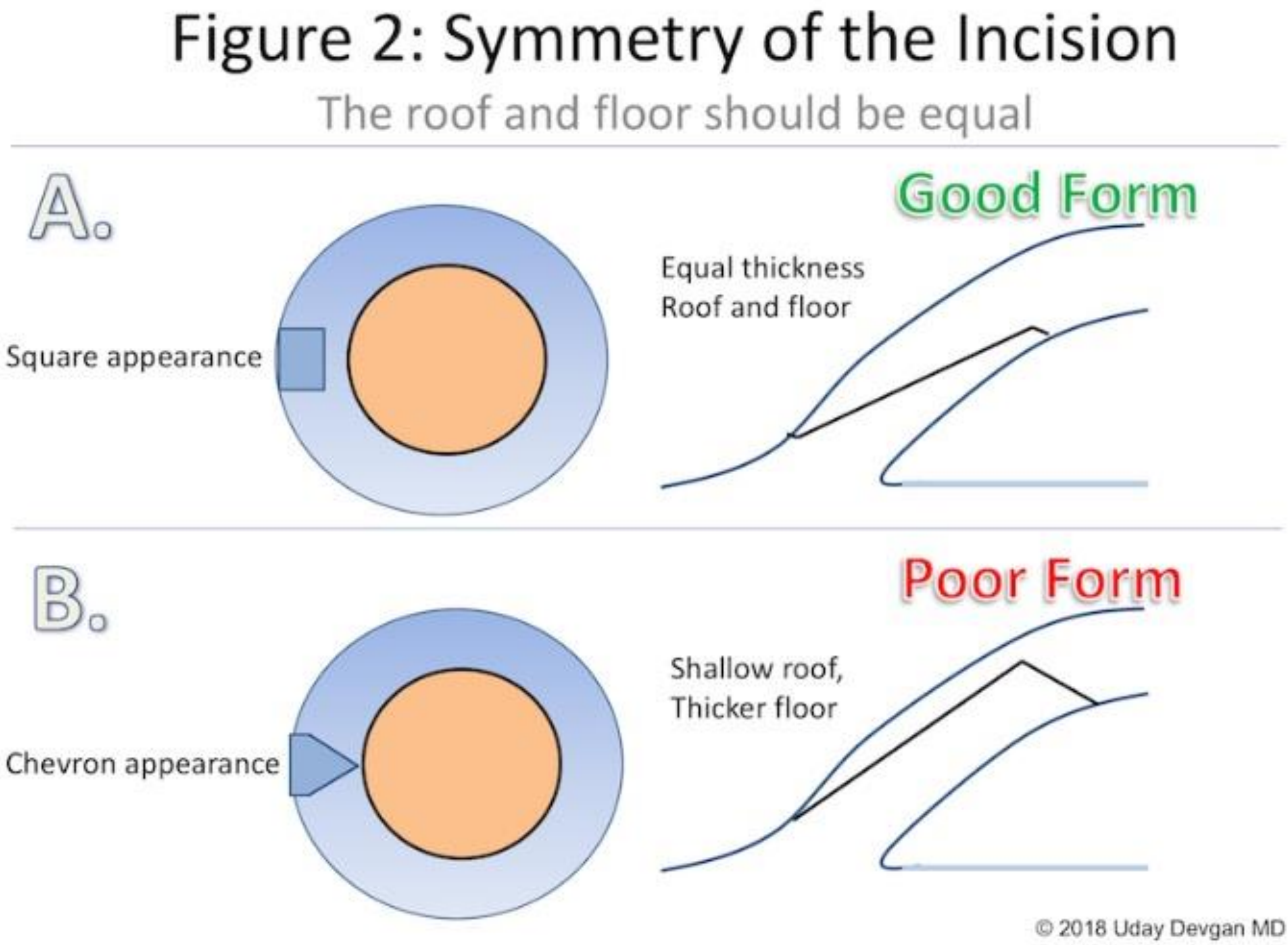


Placing the incision at the **temporal position** is **more advantageous** than placing it **superiorly**. This is because the temporal limbus is farther from the visual axis than the superior limbus, and thus the temporal incision will induce less astigmatism. In addition, most cataract patients are elderly and have against-the-rule astigmatism, which actually benefits from the placement of incisions at the 180° temporal meridian.

In most situations, a vascular, near-clear incision is better than an avascular, truly clear corneal incision.

- **Rule 2: Make the incision symmetric**

The corneal phaco incision can be single plane, dual plane or even triple plane, but for all of these variations, the key principle is to keep the incision symmetric. **The roof of the incision and the floor of the incision should be approximately equal in thickness.** This allows for a more stable incision during surgery and more secure healing after surgery. When looking at the incision under the surgical microscope or the slit lamp microscope, it should have a **rectangular or square configuration**. If the incision's entrance through Descemet's membrane has a chevron appearance, then the floor is likely too thick while the roof is quite thin.

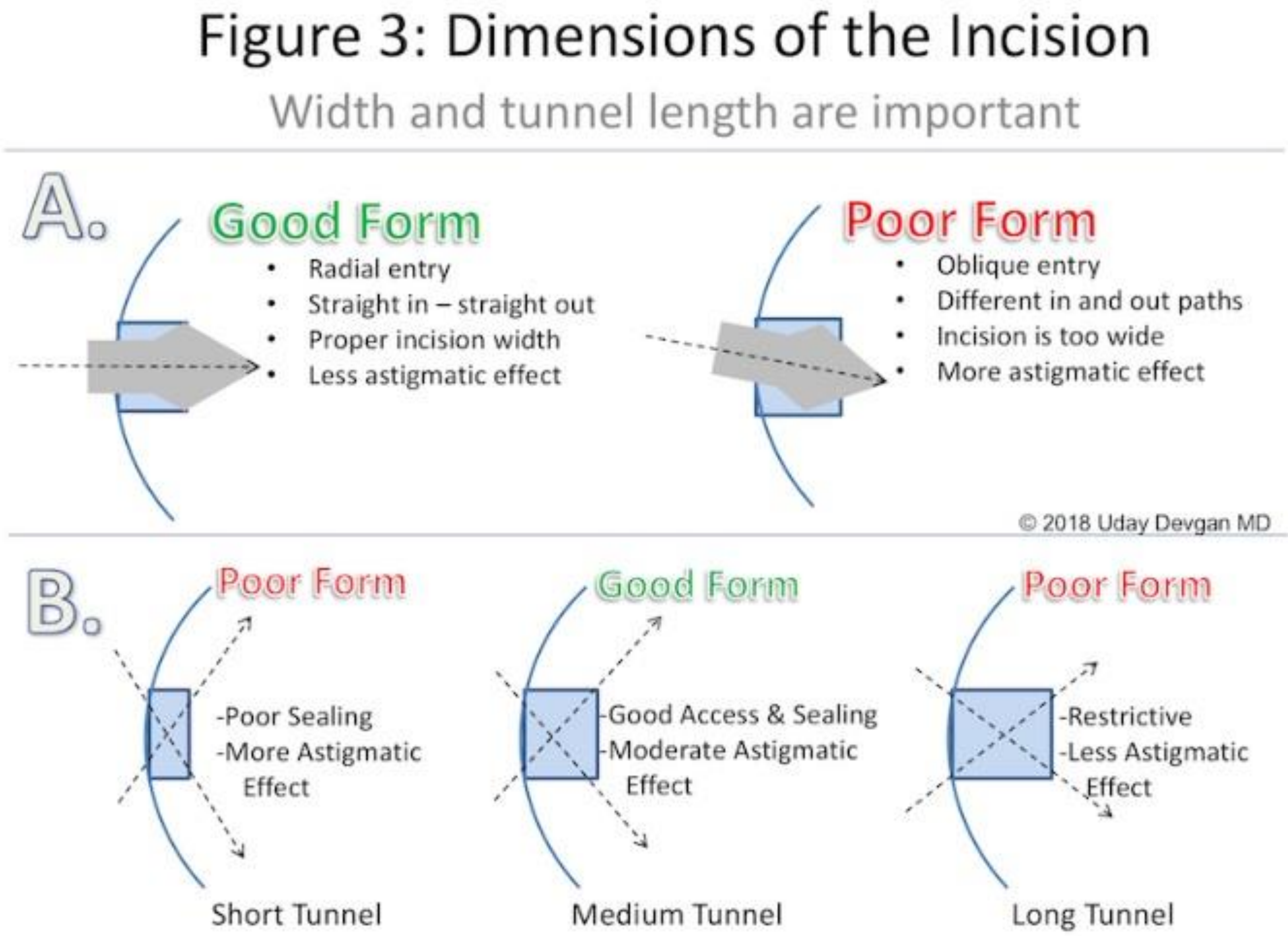


The older teaching of "**dimpling down**" to enter the anterior chamber tends to produce these chevron-shaped incisions, which are unbalanced and prone to poor sealing. **Avoid this mistake** by altering the angle of approach of the keratome blade so that the roof and floor are symmetric. In addition, this angle of approach will allow you to tailor the length of the incision to fit your needs.

❖ Rule 3: Keep the incision architecture consistent

The incision plays an important role during phacoemulsification surgery by stabilizing the fluidics in the anterior segment as well as allowing access to the cataract material. The incision width is matched to the phaco tip, irrigation/aspiration tip, and lens injector. For most surgeons, this means an incision of **between 2.4 mm and 2.8 mm in width**, although this can be even smaller for certain IOLs and larger for others. The keratome blades that we use are precision made to be the desired width, and they will perform well as long as the surgeon makes the incision radial and avoids an oblique entry. This oblique entry with different in and out paths will make the incision wider than desired, and this will lead to fluid leakage during cataract surgery, causing an unstable anterior chamber and greater risk for iatrogenic damage to the posterior capsule.

The incision should also be of a **precise tunnel length**. Too short of a tunnel will provide easy access to the anterior chamber, but it will induce more astigmatism and seal less effectively. The ability to seal at the end of surgery is partially determined by the surface area of the roof and floor of the incision. Shorter tunnels have less area for sealing compared with longer tunnels. But be warned that too long of a tunnel may seal well but it can be restrictive and lead to oar-locking of the instruments, making surgery more difficult.



The ideal incision tunnel length is typically between **2 mm and 2.5 mm** measured from the entrance through the corneal epithelium until the piercing of Descemet's membrane. This type of incision should seal well with only mild hydration required. If a corneal phaco incision does not seal adequately with mild stromal hydration, a suture should be considered to ensure a watertight closure.

6. Title: **How to suture the Phaco Incision with 10-0 Nylon**

No one is born knowing how to suture with 10-0 nylon under an operating microscope. **Your goal** should be to **place a 10-0 nylon suture in about 3 minutes**. The most dextrous residents can learn this after **100-200 practice sutures** in the wet lab, average residents require about 400-500 sutures, and those who struggle will require 800-1000 sutures.

- The **10-0 nylon suture** in the phaco incision should have these **qualities**:

- About 70 to 80% corneal depth (**never 100%, never piercing Descemet's**)

- Radial like the spokes of a bicycle wheel (**not tangential**)

- Bisecting the incision (in the case of a single suture)

- Sufficient tissue bites on both sides of the incision line

- Appropriate tension of the suture to keep the incision closed without inducing astigmatism

- **Key points:**

Before tying the suture, the anterior chamber pressure is brought to a normal, physiologic level. This is important to get the appropriate suture tension.

There are three throws: **3-1-1**, so three loops, then one, and then one more. Note that for the second throw the suture ends are turned 90 degrees because this allows the suture to cinch down a little tighter if needed.

To judge the correct tension, after throwing the second throw, the knot can be pulled side-to-side to see the overall tension of the suture. This method will allow you to throw many sutures in a row (for a larger incision) while keeping them all at about the same tension.

7. Title: **How to sculpt a nuclear groove**

Sculpting a groove in the nucleus is required for techniques such as divide-and-conquer and stop-and-chop. The groove works best when we understand how wide and deep to make it and also the path of the phaco probe required for the best efficiency and highest safety. A poorly constructed groove will make it difficult to crack the nucleus into pieces and it may also pose a risk of capsule rupture by the phaco tip.

Make sure firstly to make good CCC with good spinning for the cataractous lens

If it does not spin; you'll not win!

Start by removing some of the anterior cortical material within CCC

Sculpt a nuclear groove WITHOUT touching the CCC (deeper in the center; shallower in the periphery)

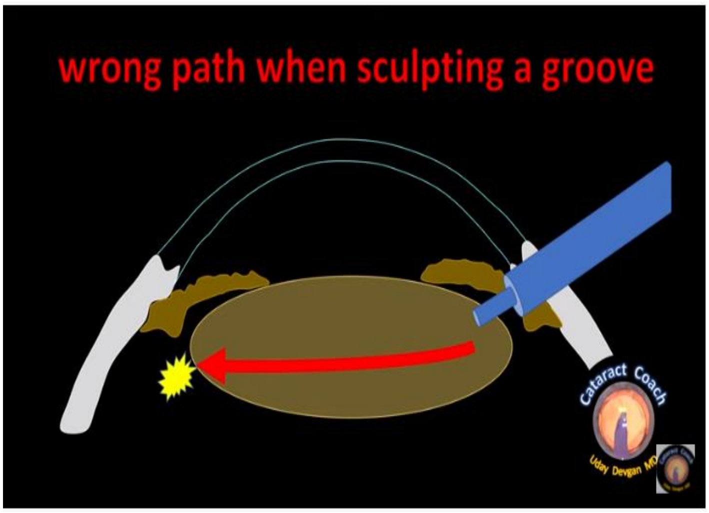
- **3 things determine a good groove:**

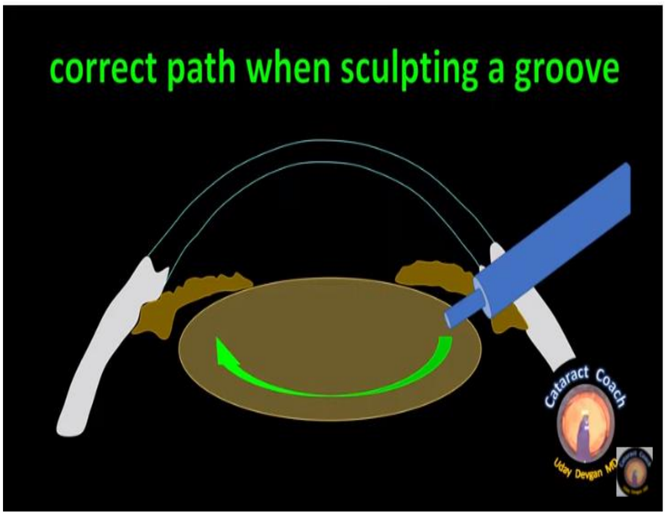
How deep? How width? What path?

- **The path**

The wrong path is parallel; you'll end up nailing the post capsule

The right path is curved path; deep in the center and shallow in the periphery; at the level of the iris





- **The width**

Phaco tip and one fourth but make sure to keep the walls of the groove straight and nice.

- **The depth**; how do you know the most appropriate depth

Some people depend on the phaco tip; 2-3 phaco tips width depend on the size you use

Some people depend on the red reflex

In the end; you judge it depend on your experience

To crack the nucleus into 2 halves easier; you should put the instruments (the chopper and phaco tip) deep in the groove i.e., in the bottom of the groove not the top

Which pedal position surgeon should to crack nucleous?

Always in position 1 (infusion only). No need for vacuum (position 2) or ultrasound power (position 3) when we are cracking the nucleus into two halves.

8. Title: **Resident surgeons must learn to load the IOL**

If you incorrectly load the IOL then you risk damaging the lens, deforming the optic, inserting it upside down, or even damaging the capsular bag.

Remember it's always **anti-S shape** loading

Put viscoelastic on it to facilitate handling

Be careful always use non-toothed forceps

Make both haptics on the surface of the optic

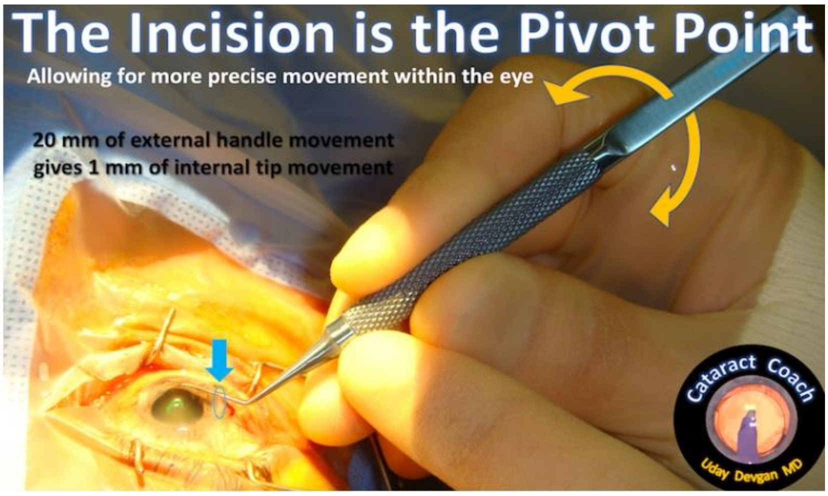
Advance it with the plunger, and deliver it in the capsular bag gently

9. Title: 3 Rules for Maneuvering Instruments in the Eye

Intra-ocular procedures pose the surgical challenge of working within a very small space with limited room in which to maneuver instruments. In this regard, our eye instrumentation is very small with fine tips that are millimeters or less in dimension. Using these instruments within the eye, such as in cataract surgery but also applicable in posterior segment procedures, requires learning to pivot within our small incisions to avoid collapse or distortion of the anterior chamber. Our goal is a minimally invasive procedure with a low degree of surgically induced trauma so that the eye is quieter with less inflammation and rapid recovery of excellent vision.

- These are the 3 Rules that Expert Cataract Surgeons always follow:

  - **Rule 1: Pivoting is the key**

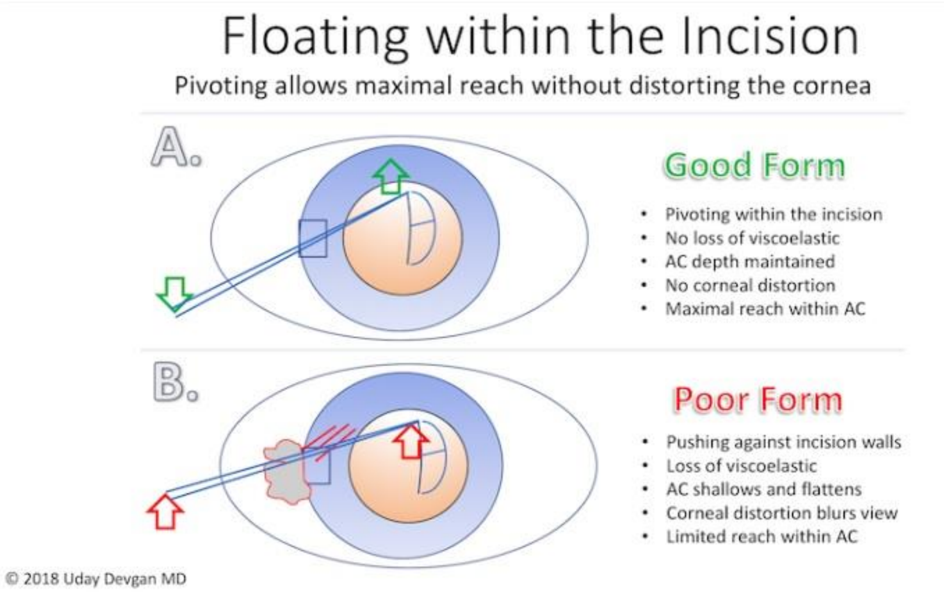


Moving any instrument with a **pivoting technique** has the advantage of allowing a wide range of movement while inserting the instrument through a smaller incision. There is the additional benefit of increasing precision since a large movement on the outside of the pivot can give a small movement inside the eye. Think of a row boat and a paddle with an oar lock. Though the part of the paddle in the water will move many yards each stroke, the handle portion of the oar moves only a few feet within the boat. With eye instruments, it is the reverse: a long handle outside the eye will move many centimeters while the short tips within the eye move just a few millimeters.

By using the pivoting technique during capsulorhexis creation, a large **20 mm** movement of the external instrument handle gives a very precise **1 mm** movement of the internal tip of the forceps, thereby increasing precision.

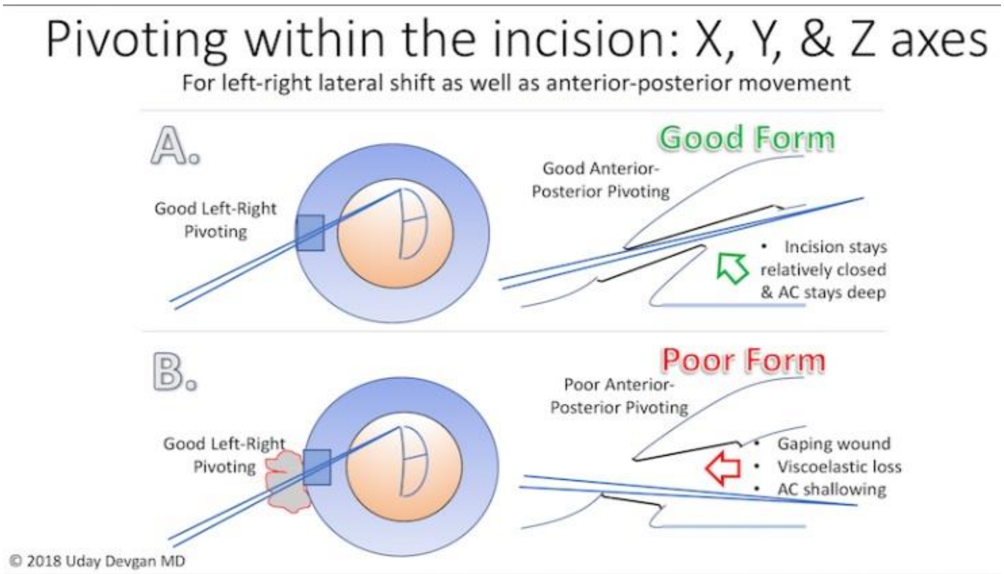
The correct form is to pivot within the incision during surgery which means that the hand of the instrument will move to the right if you wish the tip of the instrument to move left. This keeps the corneal incision relatively closed and undistorted, allows viscoelastic to be retained within the anterior chamber to maintain depth, and gives maximal reach within the eye.

The incorrect technique is to push against the incision walls, trying to move the instrument handle in the same direction as the instrument tip. This causes distortion of the cornea as the instrument pushes against the walls of the incision limiting the view and allowing viscoelastic to escape from the eye, leading to the collapse of the anterior chamber. The reach within the eye is also compromised if the surgeon does not employ the pivoting technique.



- **Rule 2: Float within the incision**

Surgery is three dimensional and we must be able to move left and right (x axis), forward and backward (y axis), and anterior and posterior (z axis). These same principles of pivoting within the incision apply in all of these dimensions. In particular, a failure to properly pivot in the z axis can lead to extensive gaping of the phaco incision which causes loss of viscoelastic or saline solution and anterior chamber collapse during cataract surgery which makes a complication such as a posterior capsular rupture far more likely.

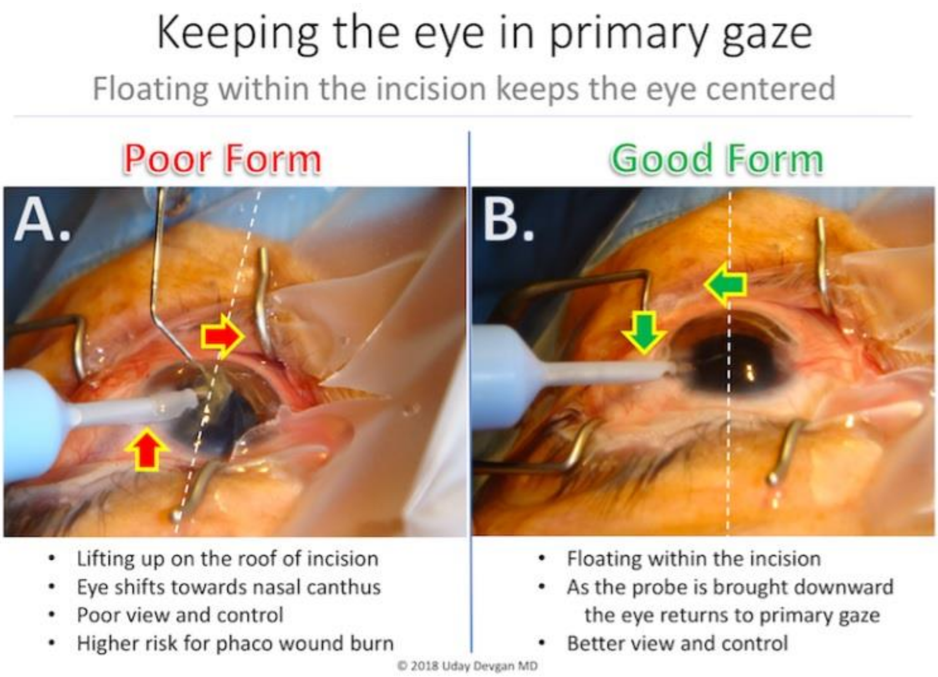


In addition to pivoting, we must also float within the phaco incision so that the eye stays in primary gaze. There is a tendency for beginning surgeons to lift up on the phaco incision which causes the eye to shift out of primary position. For temporal phaco incisions this causes the eye to move towards the nasal canthus which limits surgeon visibility and control, may cause patient discomfort, and predisposes to a phaco wound burn. When the phaco probe tip is forcefully pushed against the roof of the corneal incision, there is increased friction and heat from the ultrasonic vibrations in close proximity to the corneal stromal tissue without the benefit of adequate fluidic cooling. This leads to a phaco wound burn which can induce a large degree of irregular astigmatism and result in a poor visual result for the patient.

Also of importance is the surgeon's non-dominant hand which controls instruments such as phaco choppers which are placed through the paracentesis incision. With the surgeon focusing much of his effort on the phaco probe in the dominant hand, the hand holding the chopper can have a tendency to wander or inadvertently place pressure on the paracentesis incision. This leads to distortion and increased fluidic leakage from the paracentesis which can be enough to upset the fluidic balance of the phaco machine.

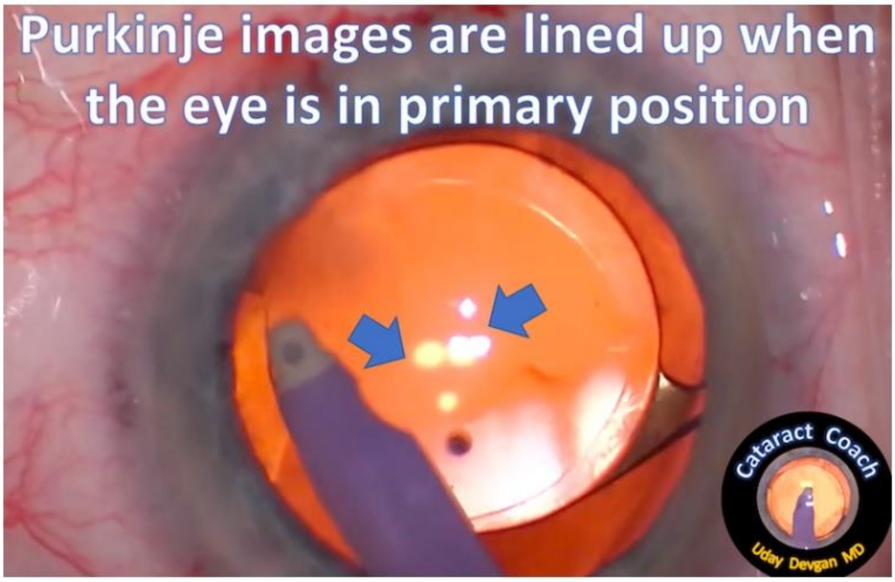
- **Rule 3: Keep the eye in primary position**

When the eye is moving towards the nasal canthus, gently bring the phaco probe downwards until the eye is back in primary gaze with the iris parallel to the floor. Remember that when instruments are inserted within the eye, it is the surgeon's movement of these tools, and not the patient's voluntary muscle control, which determines the position of the eye.



Keeping the eye in primary position gives you the best red-reflex which is helpful in seeing details such as the edge of the capsulorhexis. Looking at the reflection of the microscope lights on the cornea, make sure that this light reflex stays in the central corneal zone. The 1st Purkinje image is the reflection off the anterior corneal surface, the 2nd Purkinje image is the reflection from the posterior corneal surface, the 3rd Purkinje image is the reflection from the front of the lens, and the 4th Purkinje image is reflected from the posterior surface of the lens and it is inverted.

The blue arrows show the two strongest Purkinje images, the right arrow is the first Purkinje image from the anterior surface of the cornea while the left arrow is the fourth Purkinje image which is also inverted. When the eye is in primary position, these Purkinje images are close to each other or overlapping. In primary position the red reflex makes it easy to see details like the edge of the capsulorhexis.



Comments on the video:

anterior chamber filled with preservative-free anesthetic + epinephrine (produces radial muscle contraction-- active mydriasis to keep pupil open throughout the surgery)

injection of **dispersive** viscoelastic (eg. 2% HPMC) -- maintain anterior chamber depth, facilitate surgical maneuvres without damaging the corneal endothelium

10. Title: **Hand Positioning during Cataract Surgery**

- **Bracing the hands**

The surgeon's hands should be braced against the patient's head or alternatively, using a wrist rest. Avoid hovering with the hands in the air since this provides no support and decreases precision. Typically, the pinky finger and/or the ring finger of each hand is used to brace the hands against the patient's cheek, forehead, or orbital rim. This also provides a degree of safety because if there is an inadvertent movement of the patient's head, then the surgeon's hands move as well in the same direction and at the same time.

The hands are also positioned so that the view through the microscope is not impeded or blocked by a gloved hand. If using a fixation ring for incision creation, the non-dominant hand tilts the fixation ring handle away from the surgical field while the dominant hand uses the keratome to create the phaco incision.

- **Using both hands together**

We can also gain additional stability by using two hands to hold the instrument such as the forceps used in capsulorhexis creation. But the disadvantage is that the surgeon is unable to use each hand to do a separate task. In patients with difficulty fixating on the microscope lights, I recommend using the non-dominant hand to hold the eye by using a chopper to hook the paracentesis incision. Now the dominant hand can use the forceps to create the capsulorhexis in a perfectly still eye.

Instruments entering via incisions on the left half of the eye should generally be held primarily with the left hand, while the right-hand does the same for that half of the eye. This prevents having to cross one hand over the other to access the eye.

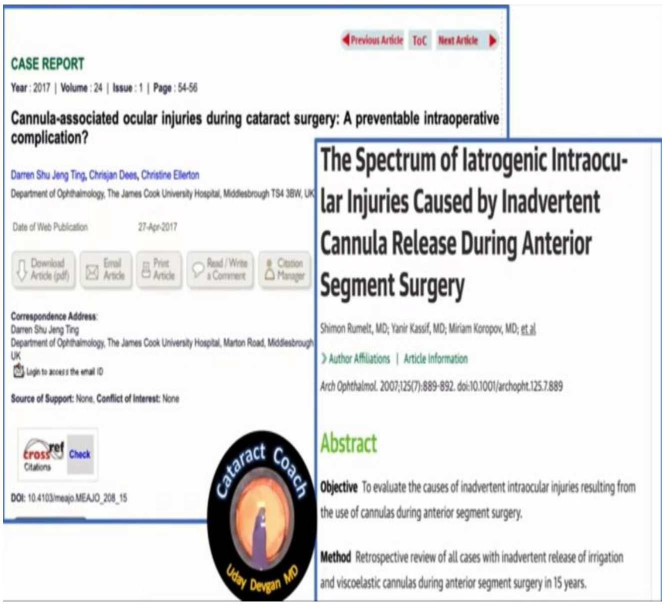
- **The natural pencil grips**

From a young age, we are taught to hold a pencil with a particular grip. We then spend decades writing thousands of pages of notes using this same grip, thereby building great dexterity. Keeping this same pencil grip makes for a natural transition to intra-ocular surgery. It is no coincidence that many of our key instruments such as the phaco probe are designed to function like pencils. This pencil grip is likely to give the highest level of precision for most surgeons and it is what I recommend for all beginning residents.

When dealing with injectable medications and fluids, care should be taken to hold the junction where the cannula attaches to the syringe. Some of our syringes feature locking mechanisms to prevent the cannula from becoming dislodged, while others use simply a friction fit. If the cannula is partially blocked, pushing on the plunger can create very high pressure that can cause the cannula to shoot from the tip. This acts like a projectile and can cause serious intra-ocular injuries such as iris damage, lens dislocation, or vitreous cavity penetration.

11. Title: **What is the correct way to hold a fluid syringe?**

When we have a syringe that is filled with liquid, we have a high-pressure situation that could result in an iatrogenic trauma and complication. The syringe is capable of causing high pressure that can cause a traditional Luer-lock cannula to shoot off into the eye and damage the delicate ocular structures. The key to using these syringes is to hold them with a firm grip at the cannula tip, much like holding a pencil tip. This prevents the cannula from shooting off the tip of the syringe if it is occluded.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CASE REPORT

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Cannula-associated ocular injuries during cataract surgery: A preventable intraoperative complication?

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The Spectrum of Iatrogenic Intraocular Injuries Caused by Inadvertent Cannula Release During Anterior Segment Surgery

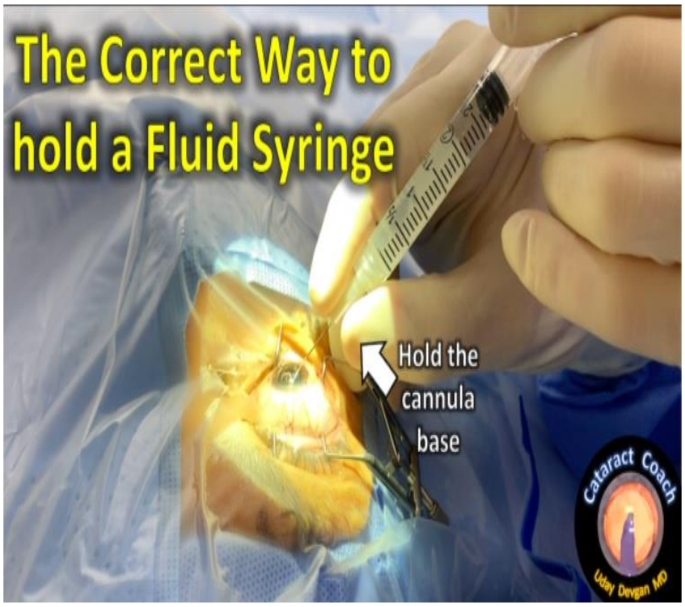
Shimon Rumelt, MD; Yanir Kassif, MD; Miriam Koropov, MD; et al

Arch Ophthalmol. 2007;125(7):889-892. doi:10.1001/archopht.125.7.889

Abstract

Objective To evaluate the causes of inadvertent intraocular injuries resulting from the use of cannulas during anterior segment surgery.

Method Retrospective review of all cases with inadvertent release of irrigation and viscoelastic cannulas during anterior segment surgery in 15 years.



12. Title: **Sub-Tenon's Anesthetic Injection Technique**

Placing anesthetic agents in the retro-bulbar space provides excellent anesthesia and akinesia during ocular surgery. Retrobulbar block carries the risk of a retrobulbar hemorrhage in rare cases. Another option for placement of local anesthetics into the muscle cone is performing a Sub-Tenon's block.

The technique is to first use topical anesthesia like tetracaine 0.5% on a sponge to numb the inferior conjunctival fornix. Then Wescott scissors and toothed forceps are used to first make a small opening in the conjunctiva and then another opening in the Tenon's layer. The

Wescott scissors are then used to bluntly dissect into the retro-bulbar space. Next 1 or 2% lidocaine without epinephrine is delivered via a blunt 19-gauge cannula into the muscle cone. Within a brief period, complete anesthesia and akinesia are achieved. Note that cranial nerve IV (the trochlear nerve) is outside of the muscle cone and is not typically blocked, therefore small movement via the superior oblique muscle may still be seen.

The small openings in the conjunctiva and Tenon's layer do not need to be sutured. They will close and heal spontaneously over the next few days.

Do we need to do any ocular massage after the sub-tenon's block?

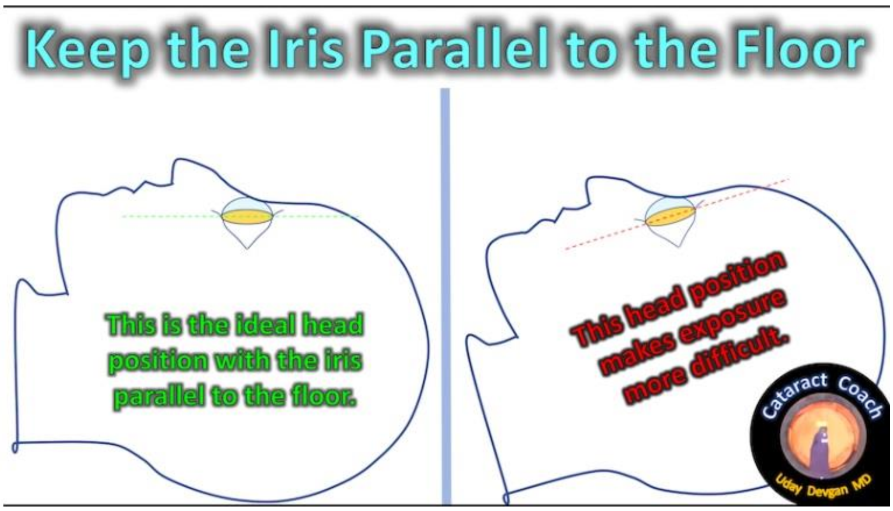
With a modest bolus of anesthetic (3cc), massage is not really necessary. Also, the large access passage allows any excess fluid to egress back up and under the conjunctiva.

Any quadrant is ok, just be sure to avoid the extraocular muscles. Try to be closer to the conjunctival fornix and farther from the limbus. About 3 cc of anesthetic is good since the typical orbit volume is 30 cc.

13. Title: **Simultaneous Hand Position and Microscope View**

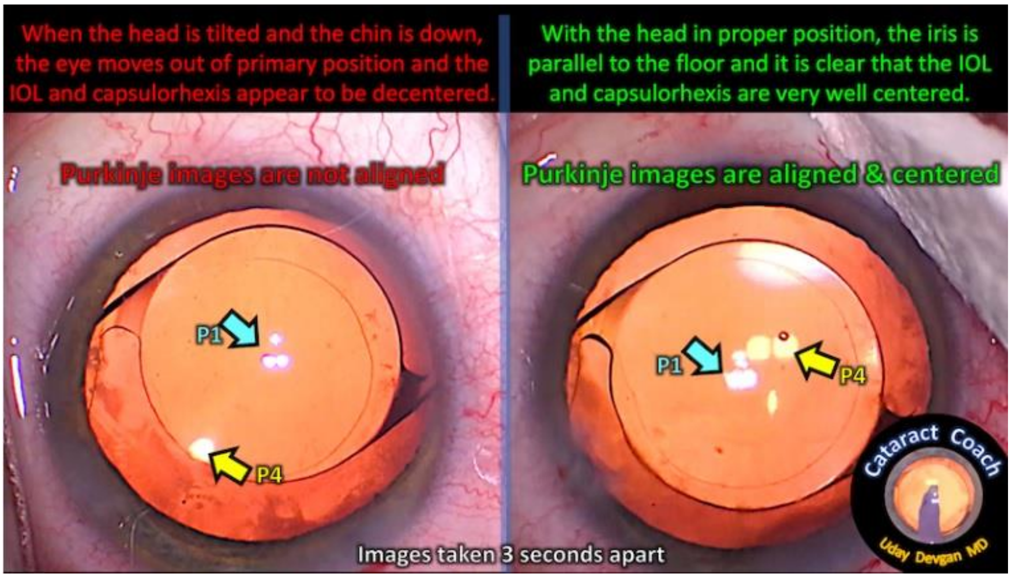
Remember that during surgery, we do not look at our hands at all: they are not in the microscope view and we don't look away from the microscope while we have instruments in the eye. The hands do their work with proprioception. For setting up the microscope and for surgeon positioning: the microscope is directly above the eye and the central viewing tube of the microscope is perpendicular to the floor of the room. Remember that the iris is also parallel to the floor. The surgeon's oculars are tilted at a slight downward angle to make it comfortable and ergonomic. My arms are bent at about a 90-degree angle at the elbow. The patient's head is positioned close to me so that I do not need to extend my arms to perform the surgery. This is my ideal setup for the microscope.

14. Title: **Position the head so the iris is parallel to the floor**



Proper positioning of the patient for cataract surgery is important for the comfort of the patient and the surgeon, but more importantly for safety and ease during surgery. With the head in proper position, the iris should be parallel to the floor of the operating room. This keeps the eye in good alignment for the surgery with a better view and easier access to the tissues.

With the chin down position, the tilt of the iris can make surgery more difficult. The patient can help by looking at the microscope light, but remember that this is the patient's up-gaze and that is more limited in range than down-gaze or lateral-gaze.



15. Title: **On-Axis Paired Incisions for Astigmatism**

Every incision that is made in the cornea can have an effect on the corneal shape, curvature, and astigmatism. The larger the incision, the greater the effect. The position of the incision also makes a difference with limbal placement having less effect than clear corneal positioning. And even making an identical incision at two different places such as the temporal limbus versus the superior limbus will make a significant difference.

Many factors go into determining how much of an astigmatic effect and incision has:

- **Width of the incision**

a larger width gives more corneal flattening

- **Tunnel length of the incision**

a shorter tunnel length gives more corneal flattening

- **Distance of the incision from the corneal center**

the farther away from the visual axis, the less astigmatic effect

- **Diameter of the cornea with respect to the incision**

the same 2.75 mm incision in a cornea with a diameter of 10 mm vs 12.5 mm will produce different astigmatic effects:

for a 10 mm diameter cornea, the circumference is ∏ x diameter = 31.4 mm and the 2.75 mm incision are about 31 degrees of arc

for a 12.5 mm diameter cornea, the circumference is 39.3 mm and the same 2.75 mm incision is only about 25 degrees of arc

- **Other properties of the cornea:**

1. Thickness/pachymetry

2. Elasticity, which can vary considerably with age

- **For non-penetrating incisions, the depth of the incision**

less effect for shallower grooves, and more effect for deeper grooves

For patients with 1 diopter or less of corneal astigmatism, corneal-based incisions such as limbal relaxing incisions or full-thickness phaco incisions placed on the axis can be enough to address astigmatism. For 1.5 diopters of more of corneal astigmatism, a better choice tends to be a toric IOL to neutralize astigmatism.

In the case presented here, the patient has about 2 diopters of with-the-rule corneal astigmatism with a steep axis of about 105 degrees. This patient is also unable to afford the cost of a toric IOL so we will attempt to lessen her corneal astigmatism by placing paired, full-thickness corneal incisions on the steep axis. This means moving the microscope so that we can operate from the superior position and then placing an inferior full-thickness corneal incision at the end of the case.

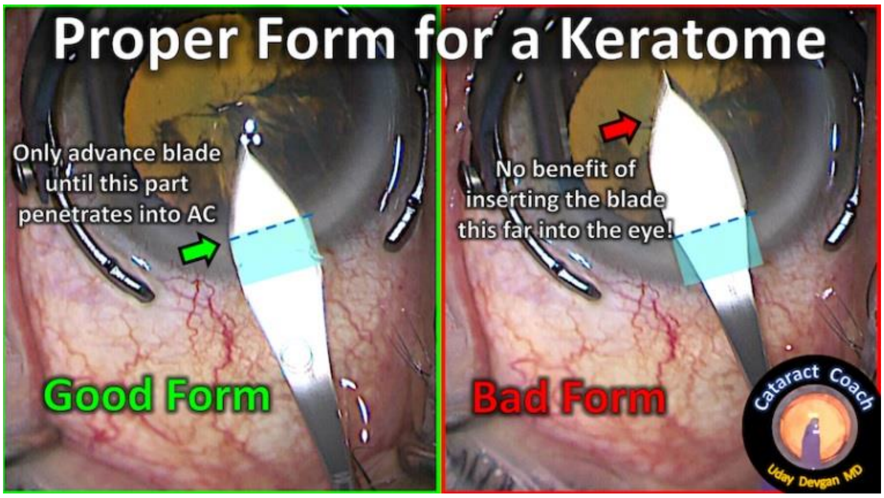
The best time to place this second incision is after the IOL is inserted and the anterior segment is still full of viscoelastic. This allows the anterior chamber to stay formed during the incision creation. Making the incision earlier in the case is not advised since it could leak during the phacoemulsification procedure which could lead to anterior chamber instability and complications such as a ruptured posterior capsule.

16. Title: **Close Up: Technique for Phaco Incision**

A poor incision can lead to an irregular capsulorhexis, anterior chamber instability during phaco leading to a ruptured capsule, and induction of irregular astigmatism that will limit the patient's future vision. Check out the technique: https://www.youtube.com/watch?v=EFflzShTWJE

#1: Have a normal physiologic IOP; doing so by injecting OVD

#2: I wrote previously the principles behind that including the angle, width, length, and depth of the incision.



We have taught that we only want to insert the keratome until the widest part of the blade has hit Descemet's layer.

There is one source of fluidic inflow: the balanced salt solution from the irrigation bottle or bag. But there are two sources of fluidic outflow: what you aspirate through the phaco tip and what leaks from the incisions. In this case, we have dramatically increased the leakage from the incision. To compensate, we can put a piece of a sponge in the incision or use a suture to one side of the incision to make the fit tighter. Or we can adjust the fluidic parameters: increase the bottle height/infusion pressure and decrease the aspiration flow rate.

The anterior chamber instability leads to iris prolapse which then causes pupillary miosis. And then the phaco probe inadvertently engages the iris and before you know it, there is a significant degree of iris damage.

#Note: I combined this lesson with 1225: a bad incision leads to iris damage

"Perfection is the enemy of good"

17. Title: **Tracing a Circle to make the Capsulorhexis**

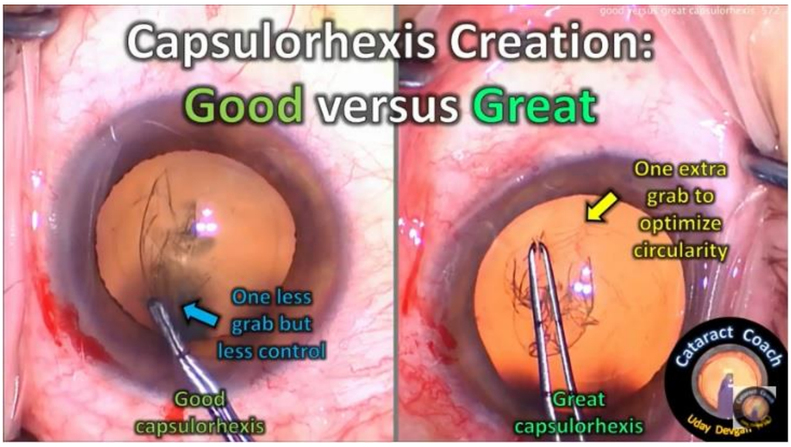
The capsulorhexis is crucial in cataract surgery because it gives capsular integrity during nucleus and cortex removal and also provides a secure overlap to hold the IOL. The capsulorhexis is also part of your signature that all future ophthalmologists and optometrists will see in the future.

A very simple technique for new surgeons who are struggling with capsulorhexis is to trace the intended path with the tips of the forceps. If the forceps tip traces a circle, then a perfect capsulorhexis will follow.

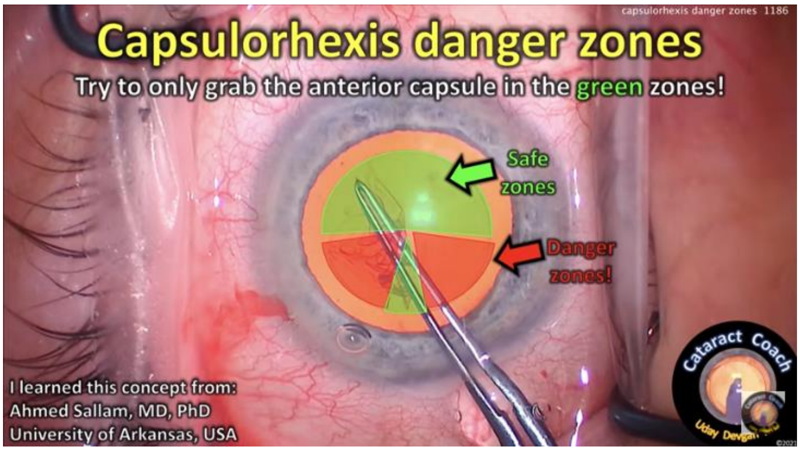
It sounds very easy, but there are **some important caveats**:

- The forceps must float in the incision and avoid gaping it open because this will cause loss of the viscoelastic and then shallowing of the anterior chamber

- The forceps must trace this circle by pivoting within the incision since this motion allows creation of accurate curves
- The anterior capsule should be grabbed appropriately with care taken to keep the flap folded over for the most control.



In this picture, the capsulorhexis on the left is good because it is centered, continuous, and an appropriate size, but it's not as pretty or circular as the great capsulorhexis on the left. How can we improve our technique in order to make a consistently great capsulorhexis? **One of the keys is to maintain good control of the capsulorhexis by re-grabbing as many times as needed.**



Grasping the capsulorhexis while it is in red zones (on the right and left of phaco incision) is a high-risk maneuver that may result in loss of control. (Difficult for your ergonomics)

18. Title: **Hydro-Dissection versus Hydro-Delineation**

Once the capsulorhexis has been created, it is helpful to use a balanced salt solution to loosen and separate the cataract from the capsular bag in order to facilitate its removal. The two primary techniques are hydro-dissection and hydro-delineation, both of which are performed using a blunt **27-gauge cannula** on a 3cc syringe filled with a balanced salt solution.

Hydro-dissection is performed between the capsule and the cataract cortex in order to free the adhesions of the cataract from the capsular bag and allow it to rotate fully. Care is taken to place the blunt cannula under the edge of the anterior capsulorhexis and towards the lens equator. You should stop shy of the lens equator as you do not want to puncture the lens capsule or damage the zonules. Keep the cannula still so that it forms a tight seal between the capsule edge and the cataract. If you move too much and loosen this seal, the fluid will come back toward you and not go forwards.

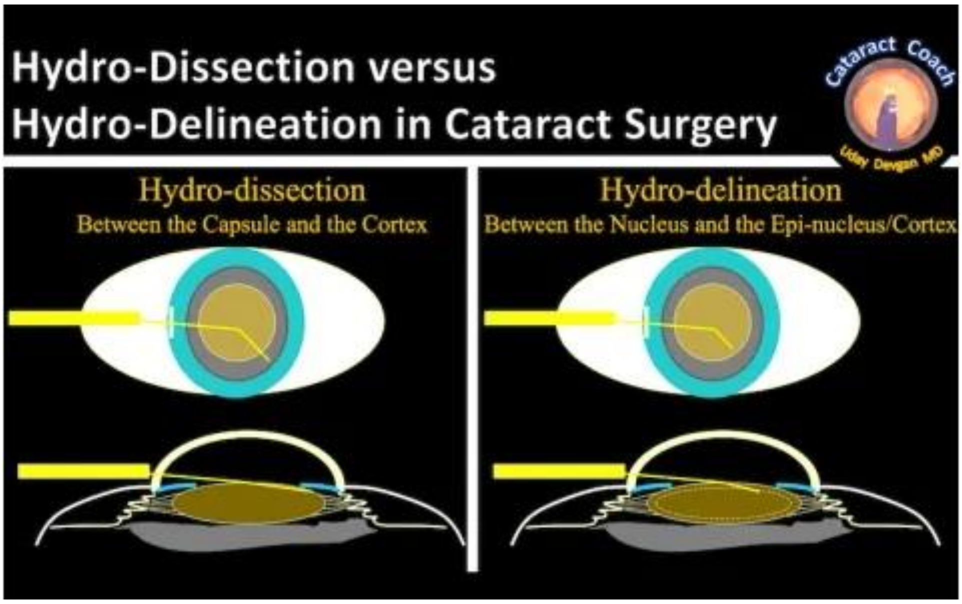
Next, gently press on the plunger of the syringe in order to send the balanced salt solution around the posterior aspect of the cataract. You want to see at least one fluid wave propagated around the cataract, and more waves are better. As the waves propagate, they will loosen the cataract from the capsular bag and some fluid may become trapped behind. To release this fluid, use the cannula to gently tap on the center of the nucleus and the fluid will be pushed anterior. The key here is to be gentle so that force is not used as this could cause the capsule to rupture and the nucleus to sublux into the vitreous.

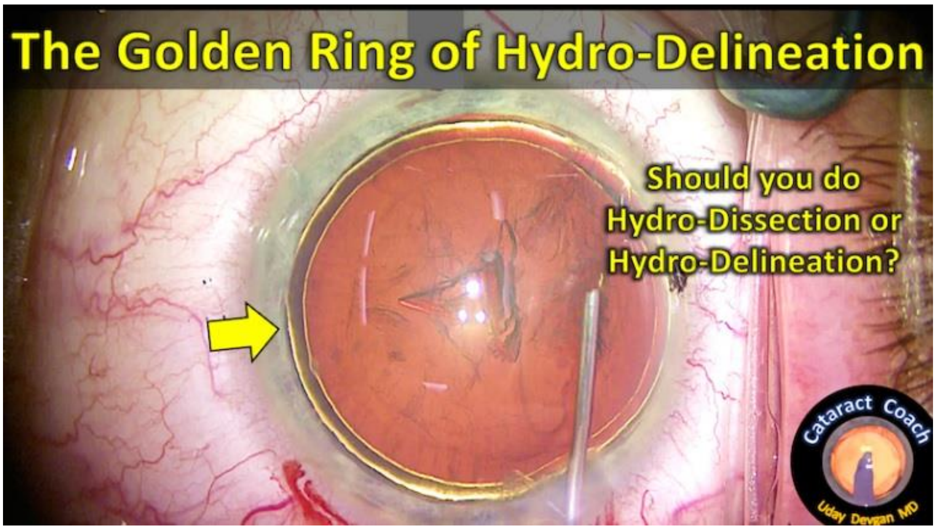
How much force is used? Very little, since the key is slow and steady. To give you an idea of the force used, if you take the 3-cc syringe with the 27-gauge cannula and inject it outside of the eye, it would form a gentle arc of fluid that would extend only a few inches. If your level of force causes the fluid to shoot across the room, you are being much too forceful. This requires a steady hand and a good sense of fluid control.

Hydro-delineation is to separate the endo-nucleus from the epi-nucleus. The central endo-nucleus is of a higher density and requires more ultrasound energy to remove, while the epi-nuclear shell is softer and easier to remove. This is an **optional step** that is performed with the idea that the epi-nuclear shell can act to protect the posterior capsule during phacoemulsification of the endo-nucleus. **Many surgeons do not perform this step**, and instead prefer to remove the entire nucleus without separating it into these layers.

To prevent the fluid from the cannula from going between the capsule and the cataract, which was already performed during hydrodissection, the tip of the cannula should be placed within the edge of the capsulorhexis and not beyond it. Dig the tip of the cannula into the nuclear material while keeping it within the confines of the 5 mm capsulorhexis. This will allow proper hydrodelineation and a successful fluid wave will result in the **"golden ring" appearance** at the area of separation.

Once the cataract has been freed from the capsule with hydrodissection and split into endo-nuclear and epi-nuclear sections with hydrodelineation, we are ready to perform nucleus removal using the ultrasound energy from the phaco probe.





Hydro-delineation is useful in cases of posterior polar cataract and when CCC is smaller than what you expect.

"A Young surgeon is so aggressive that may kill you"

"An old surgeon is so lazy that may watch you die"

19. **Phaco Fundamentals Series**

I. Title: **phaco parameters for efficiency**

Two points to keep in mind: 1. There are no magical phaco settings.

2. The fluidic settings depend on the size of the phaco tip and phaco sleeve.

Dr. Devgan explained it as milk pocket and tip (smaller tip; needs more flow to drink and vice versa)

II. Title: **Phaco Fundamentals Part 1: Choosing Steps of Surgery**

Cataract surgery can be divided into multiple steps, each of which benefits from optimized fluidic settings. Let's review the typical progression of steps:

- **Pre-Phaco** is a setting used to aspirate some of the anterior cortex within the confines of the capsulorhexis in order to provide better access to the nucleus. Low flow, low vacuum, and low phaco power are used.
- **Sculpt** is the setting used to create a groove or trench, using low flow, low vacuum, and moderate phaco power, for techniques such as Divide-and-Conquer or Stop-and-Chop
- **Chop** settings have a much higher vacuum to provide holding power on the nucleus so that the phaco chop technique can be used. Quadrant removal settings are similar but may have higher flow rates to bring the nuclear pieces to the phaco tip.
- **Epinucleus** settings are all about creating appropriate flow in the eye, which, along with moderate vacuum, can be used to aspirate the epi-nuclear shell
- **Cortex** setting is for use with the irrigation/aspiration probe where we want a high vacuum and moderate flow to grab and remove lens cortical material
- **Polish** setting has low vacuum and low flow to help gently polish the capsular bag and in particular the posterior capsule with a lower risk of iatrogenic damage
- **Viscoleastic** setting is to flush out and aspirate the viscoelastic from the eye at the end of the surgery so it has a high flow rate in addition to a high vacuum level

Note that all surgeons will not use all of these settings. For example. in my typical routine cataract, I use just three settings:

- **Chop** setting to break up and remove the lens nucleus
- **Cortex** setting to aspirate the lens cortical material
- **Viscoelastic** setting to flush out and remove any residual viscoelastic

Finally, there are also settings that can be saved for unusual cases such as:

- **coagulation** which is a cautery mode to help with hemostasis
- **anterior vitrectomy** which is not used unless we have vitreous prolapse and capsular bag compromise

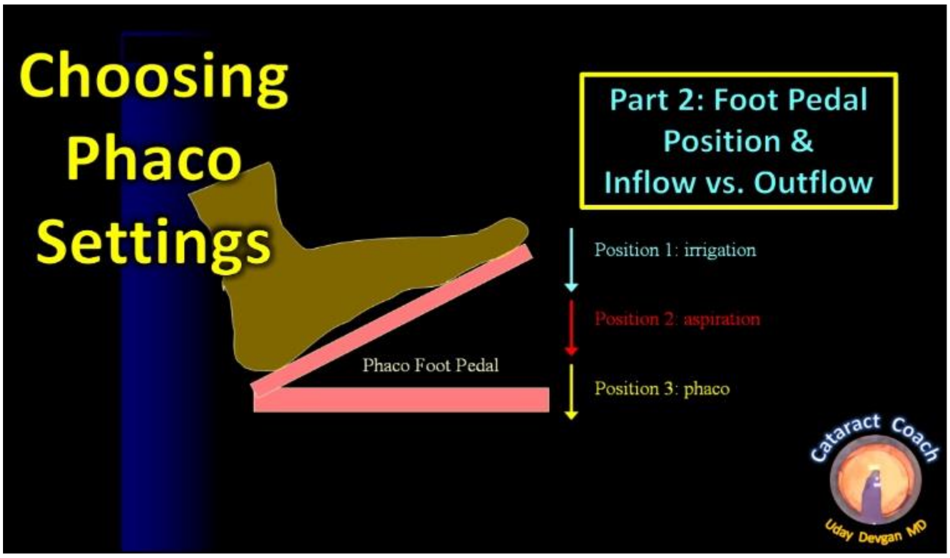
Comments from the video: PEL; patient eye level should be at the level of side light; why is this important?

Because the difference between BSS bottle high and PEL is going to be the infusion pressure

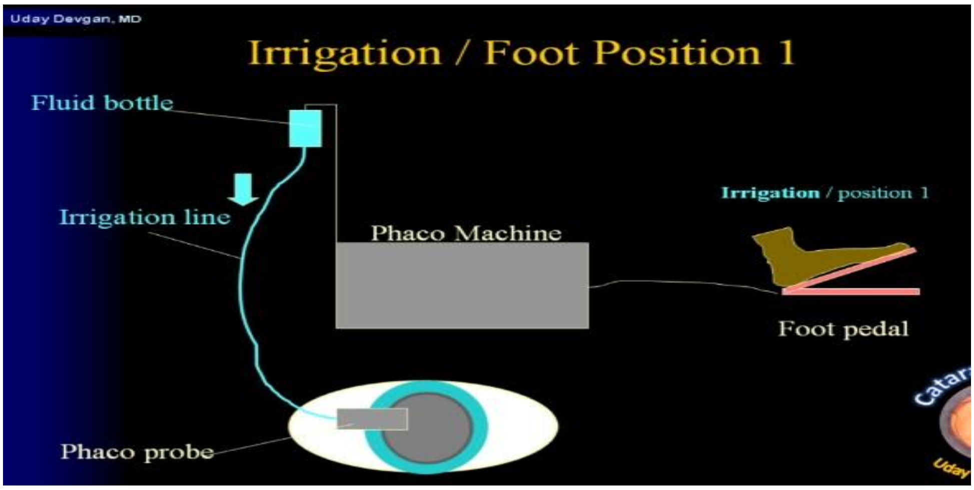
III. Title: **Phaco Fundamentals Part 2: Foot Pedal & Inflow/Outflow**

The three main functions of the phaco machine are: (1) to provide irrigation into the eye, (2) to create a vacuum/aspiration to remove the cataract, and (3) to deliver ultrasound energy in order to emulsify the nucleus. These three functions correspond to the three phaco foot-pedal positions.

The phaco foot pedal is the primary instrument used to control the phaco machine during cataract surgery. This foot pedal traditionally works by depressing it towards the floor with the dominant foot (the right foot for most surgeons). Each foot pedal position is additive to the previous positions so that while the pedal is in position 2 (vacuum/aspiration) it is also providing the full function of position 1 (irrigation). Similarly, once the pedal is in foot position 3 (ultrasound energy), it is also providing the function of position 2 (vacuum/aspiration), as well as position 1 (irrigation).



- **Foot Position 1: Irrigation**

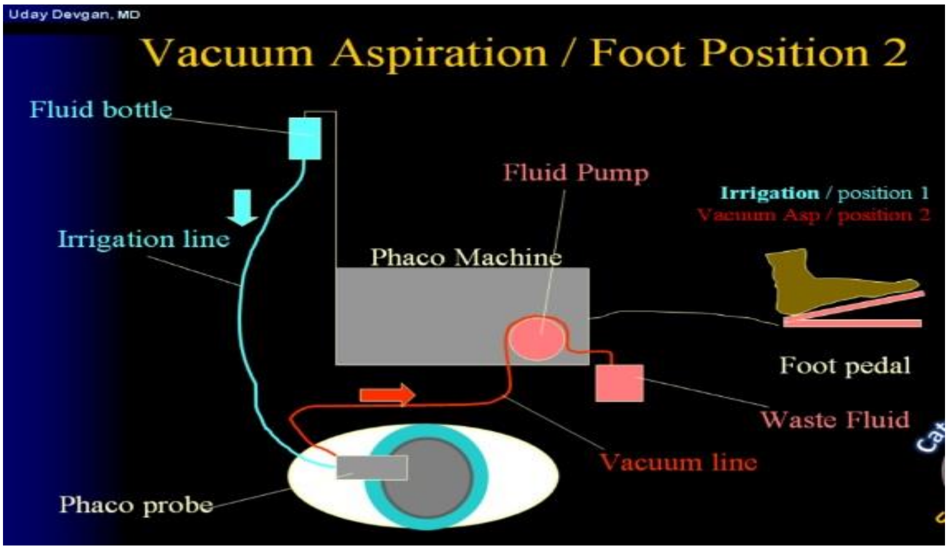


During the surgery, we must always maintain the stability and structure within the eye, particularly to prevent collapse of the anterior and posterior chambers which can lead to severe complications.

The irrigation function of the phaco machine is meant to provide a source of fluid infusion into the eye during the surgery. By depressing the foot pedal to position 1, the infusion is turned on. There is **no linear control of the infusion** – the infusion is either turned on or turned off.

The height of the infusion bottle determines the relative infusion pressure and flow rate during the surgery. To keep the eye inflated during surgery, we need to make sure that the fluid inflow rate is greater than the fluid outflow rate.

- **Foot Position 2: Vacuum / Aspiration of fluid**

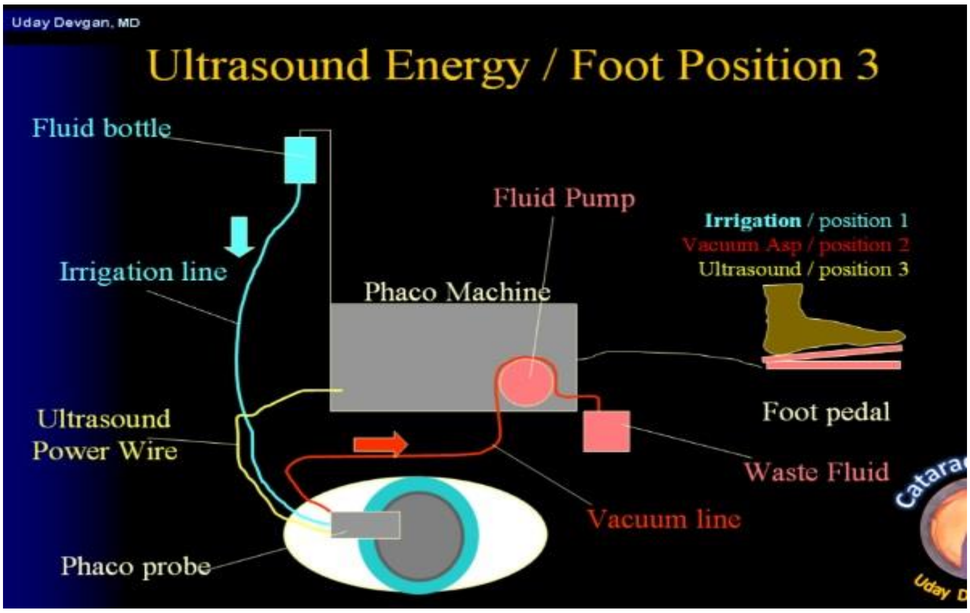


Phaco foot position 2 is the control of the relative aspiration and vacuum level of the fluid from the eye. There is a **linear control of vacuum and flow**, so that the top of foot position 2 provides less vacuum or flow than the middle or bottom range of the same foot position 2. This is similar to the gas pedal in a car, where the car's throttle is opened more as the gas pedal is further depressed.

To create the vacuum and the aspiration flow of fluid, the phaco machine must have a fluid pump. **The most common types of fluid pumps are peristaltic and venturi.**

The vacuum and aspiration levels that are created draw the fluid out of the eye and into a waste fluid collection via the outflow tubing. The regulation of vacuum and aspiration is controlled by the foot pedal, with more depression of the pedal resulting in higher levels. **There are two primary sources of fluid outflow during phacoemulsification: the outflow from the phaco probe created by the fluid pump, and the leakage of fluid from the incisions.**

- **Foot Position 3: Ultrasound Energy**

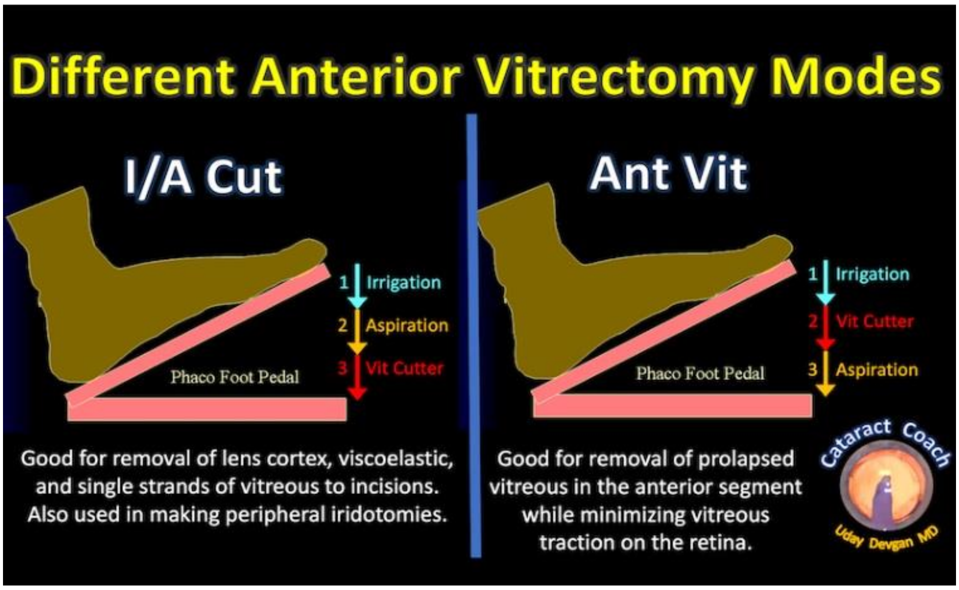


The bottom-most position of the foot pedal is position 3, which controls the delivery of ultrasound energy into the cataract. There is linear control of the ultrasound energy level so that further pedal depression results in more ultrasound energy, such as would be needed for a denser cataract.

Note that if the pedal is in position 3, we are already engaging the full function of both positions 1 and 2. The irrigation is on, and the vacuum and aspiration level is at its highest preset level. Ultrasound energy should only be applied once the tip of the phaco probe is in contact with part of the cataract.

When we look at the phaco probe closely, we see that there are three lines attached: (1) the infusion tubing carrying fluid into the eye, (2) the outflow tubing that removes the fluid via flow that is created by the phaco machine's fluid pump, and (3) the line that carries the electrical signals to control the ultrasound energy at the tip of the phaco probe. These three lines correspond to the three phaco foot pedal positions.

- **Changing Pedal Functions for Anterior Vitrectomy**



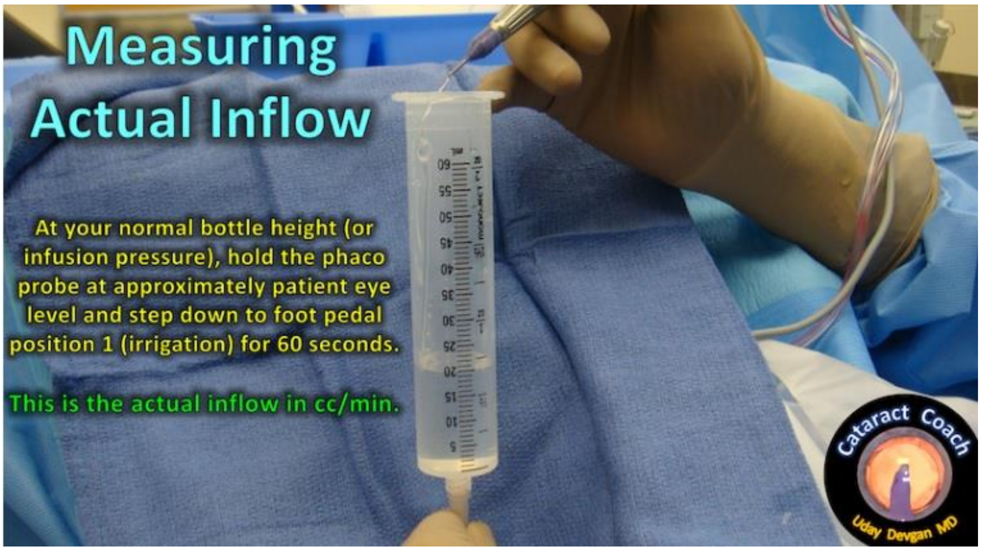
There are two distinct modes under the anterior vitrectomy setting of your phaco machine and they change the function of foot pedal positions 2 and 3.

I/A Cut: This means that your foot pedal does: position 1 irrigation, position 2 aspiration, and position 3 the mechanical cutting action. **It is in the same order as the name "I/A Cut" –** 1. Irrigation, 2. Aspiration, 3. Cut. This is great for aspirating cortex material or removing viscoelastic at the end of the case. **Do not use this mode for removing the vitreous since it will put traction on the vitreous and that could damage the retina.** If you hear the ding sound that the machine makes when it is occluded, you likely have vitreous blocking the port and you should not be using this mode.

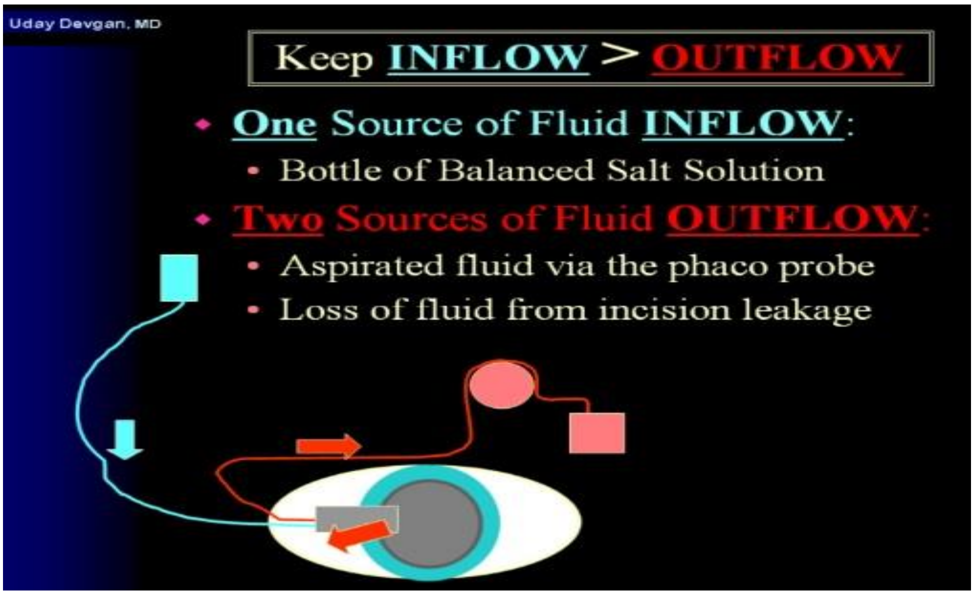
Anterior Vitrectomy: This means that your foot pedal does: position 1 irrigation, position 2 mechanical cutting action, and position 3 aspiration. **This is great for removing prolapsed vitreous**, but it does not work well for stripping away cortex material. This mode will help minimize the traction that the vitreous can place on the retina, which helps lower the risk of a retinal break or detachment. Also, be careful as this mode can easily damage the remaining capsular support or even the iris.

- **Measuring Actual Inflow**

The vast majority of cataract surgeons have never measured the actual inflow of fluid during surgery and phaco machines do not track this value either. With your normal bottle height (or infusion pressure), hold the phaco probe at approximately patient eye level. This is important because the infusion pressure and flow will be determined by this height difference, much like a water tower in a residential neighborhood. Now step down to foot pedal position 1 (irrigation) for 60 seconds and collect the balanced salt solution. In the picture here, I am using an empty 60 cc syringe as a measuring cup or cylinder. The total amount of fluid during the 60 seconds will be the actual inflow rate measured in cc/minute. This value changes based on the phaco needle, sleeve, and tubing being used as well as the bottle height and patient eye level.



- **Always keep Inflow balanced with Outflow**



Due to the small volume of the anterior and posterior chambers, the control of fluidics during phacoemulsification surgery is important to ensure efficient removal of the cataract while preventing complications due to tissue collapse. Balanced fluidics means that the infusion pressure is sufficient to keep up with the outflow of fluid and that gives a stable anterior chamber and prevents the posterior capsule from flapping uncontrollably in the fluid currents.

Remember that there is just one source of inflow: the balanced salt solution from the infusion bottle or bag. There are two sources of fluid outflow: most of it is aspirated by the phaco handpiece (or I/A handpiece for cortex removal), but there is also fluid leakage from the incisions. We want a small amount of fluid leakage from the main incision since this cools the phaco probe which would otherwise get very hot from friction due to the ultrasonic motion.

In the example above, if we measured the actual inflow to be 60 cc/min, then we should expect up to 10 cc/min of fluid leakage from the incisions. This leaves us with a maximum advisable outflow rate of 50 cc/minute which we determine from our fluidic pump settings.

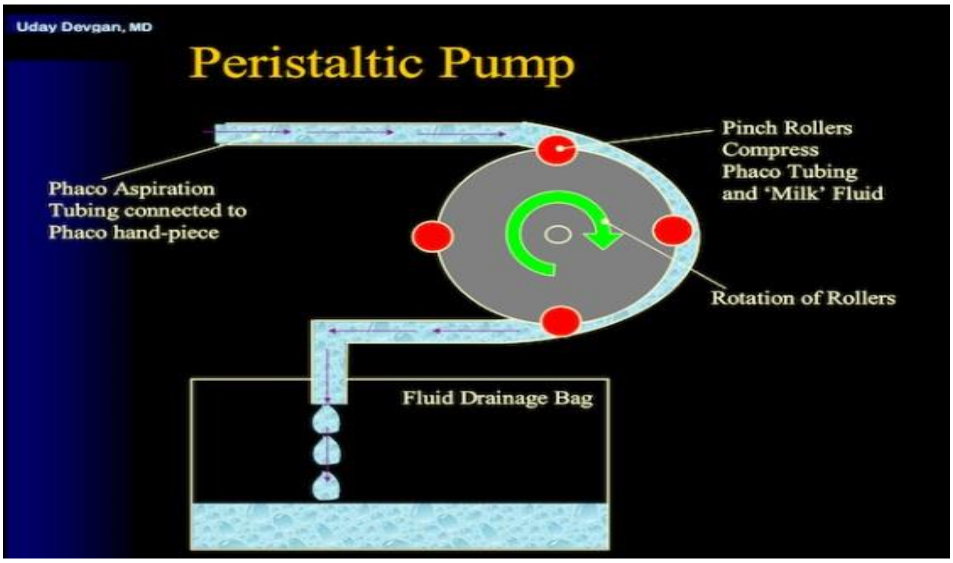
The basic concept of fluidics is that the inflow of fluid must be greater than the outflow of fluid. By keeping a constant infusion pressure and limiting the outflow, we can ensure that the eye stays inflated and stable during surgery. If we allow the outflow to exceed the fluid inflow, even for just a fraction of a second, we experience a surge within the eye and this can cause chamber instability, the collapse of the eye, and aspiration of the posterior capsule. **The primary rule for phaco fluidics is to keep the inflow greater than the outflow.**

IV. Title: **Phaco Fundamentals Part 3: Peristaltic vs Venturi Pumps**

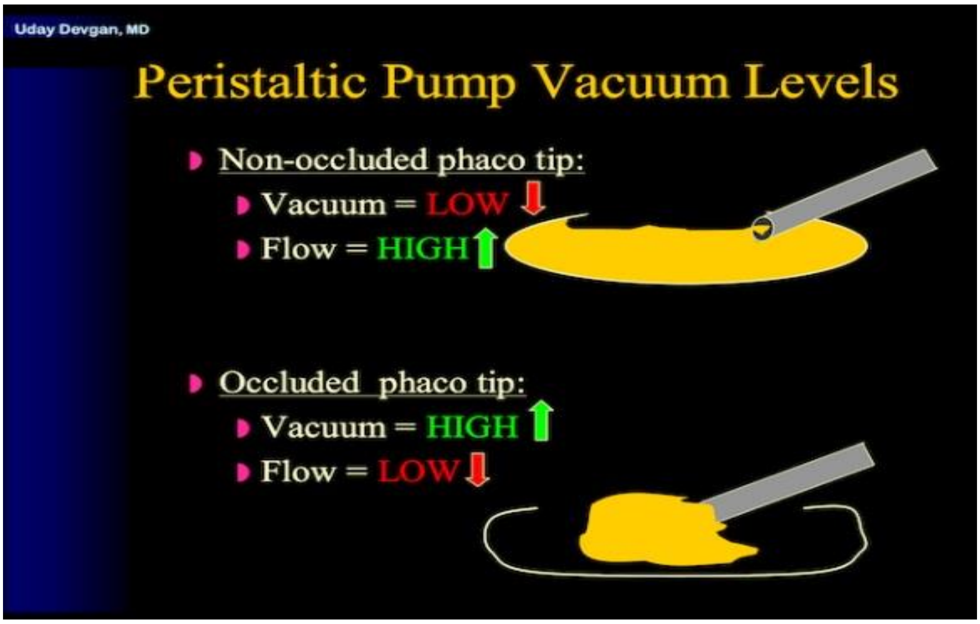
Two primary vacuum pumps are used in phacoemulsification platforms — peristaltic and venturi. Although they work in different ways, each has its advantages.

- **Peristaltic pump (flow-based)**

The peristaltic pump uses rollers to compress the phaco outflow tubing in a peristaltic manner, thereby creating flow and vacuum. The compression of the rollers on the tubing with the rotation of the pump physically moves fluid and creates a continuous “milking” action on the fluid column. The phaco machine can directly control this flow level, hence the term flow based; however, the preset vacuum level is only achieved once there is occlusion of the outflow line, typically at the phaco needle tip with cataract material.

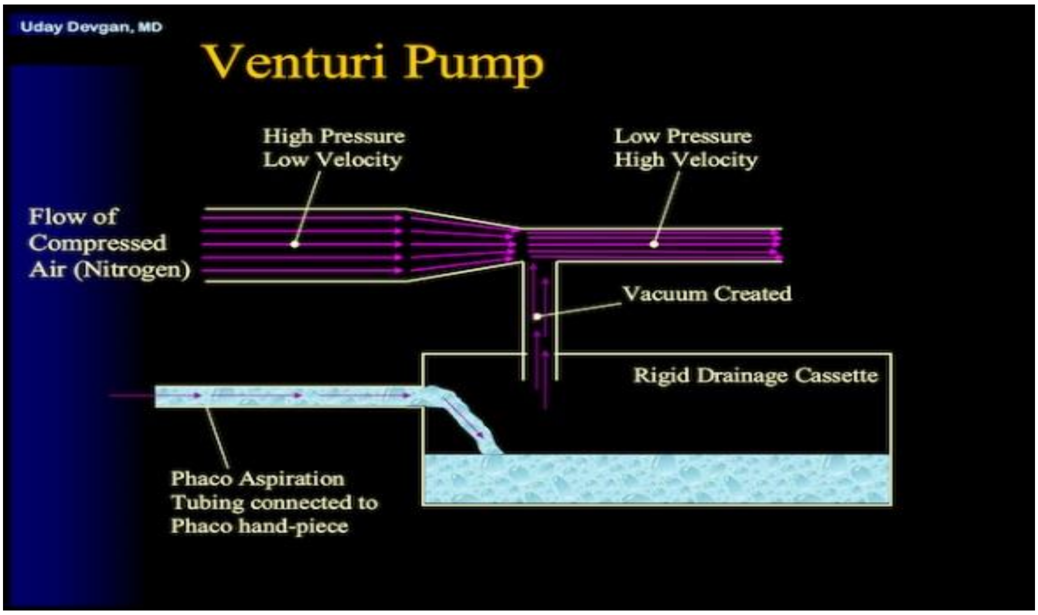


As the occlusion happens, the vacuum builds, the rollers slow down, and the outflow level decreases. Most manufacturers pre-program how the rollers slow down once an occlusion happens at the tip. However, some machines also allow surgeons to program this speed based on their technique. Thus, if you want a faster or slower “rise time” to the maximum value of vacuum, this can be programmed into the system. On complete occlusion, the rollers come to a stop, the outflow approaches zero, and the vacuum is at its highest level.

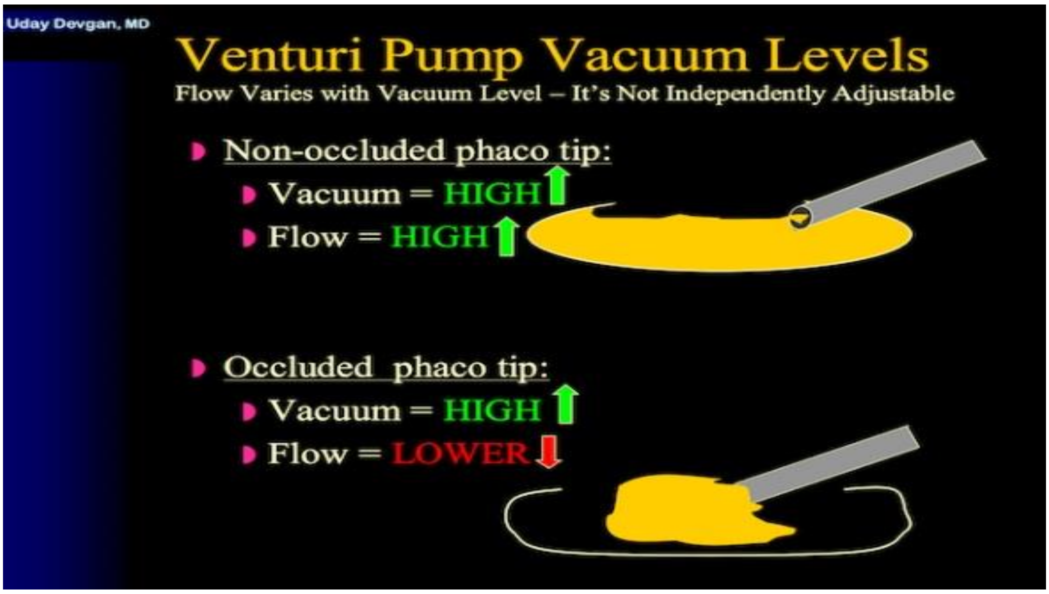


- **Venturi pump (vacuum based)**

The venturi pump makes use of the venturi effect to create a vacuum. The venturi effect creates a vacuum through the flow of a fluid, typically air, over an opening. In our phaco machines, this requires nitrogen tanks or a self-contained air compressor. The vacuum level is created within a rigid drainage cassette, to which the phaco aspiration tubing is connected. Since there is no milking of the aspiration line, the phaco tubing can be made rigid with low compliance.

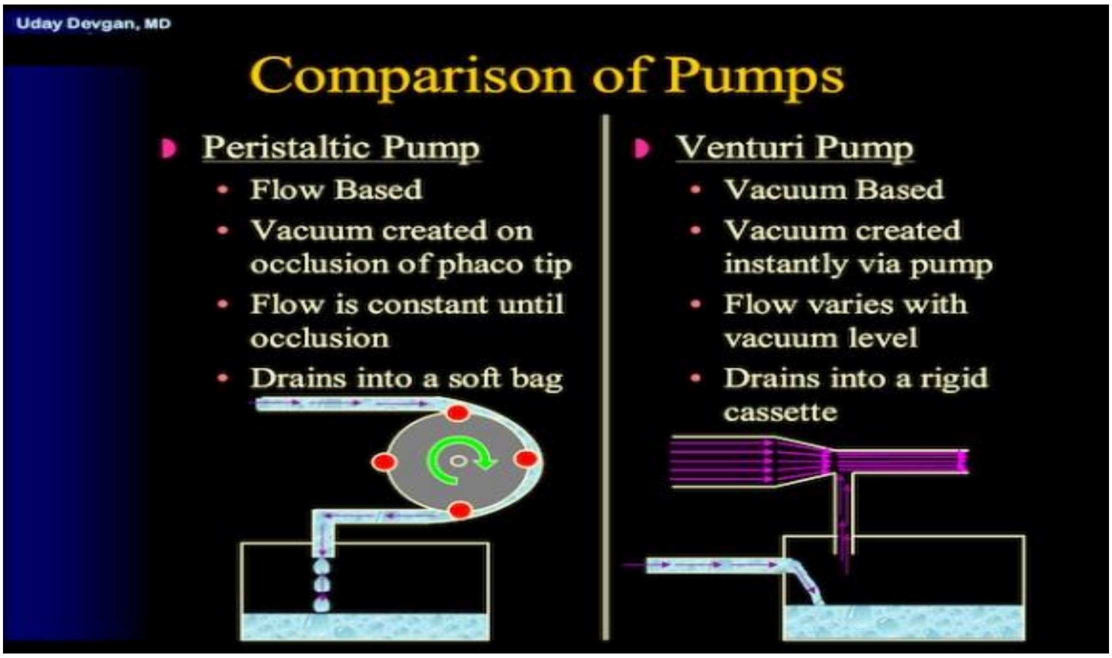


The advantage of the venturi pump is that it is able to create the preset vacuum level without occlusion of the phaco needle tip. When the surgeon depresses the foot pedal, the preset vacuum level is immediately created, hence the term vacuum based. The outflow rate is variable and is determined by the vacuum level created; the surgeon cannot directly set it. The venturi and other vacuum-based systems typically have had the advantage of much faster rise time upon occlusion as well as the potential for much higher effective flow rates within the eye.



- **Differences**

Due to these differences, operating with these two fluid pumps is somewhat different. To create the preset maximum vacuum level with a peristaltic pump, there must be complete occlusion of the phaco needle with cataract material. To create the preset vacuum level with a venturi pump, the surgeon simply needs to depress the foot pedal. For surgeons doing split infusion bimanual cataract surgery, the peristaltic pump allows a maximum flow rate to be set so that the limited inflow from the smaller-bore infusion instruments is not outstripped. Currently in the United States, the most commonly used fluid pumps are of the peristaltic design for cataract surgeons, while vitreo-retinal surgeons primarily use venturi design fluid pumps.

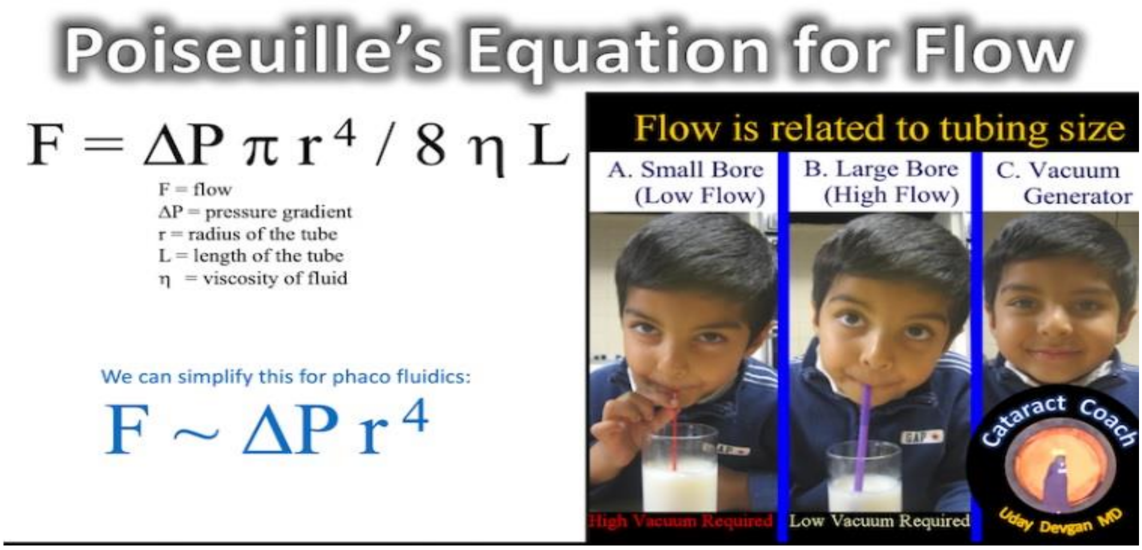


"a good workman never blames his tools", an old saying.

"Your hands are more important than your machines", Uday Devgan.

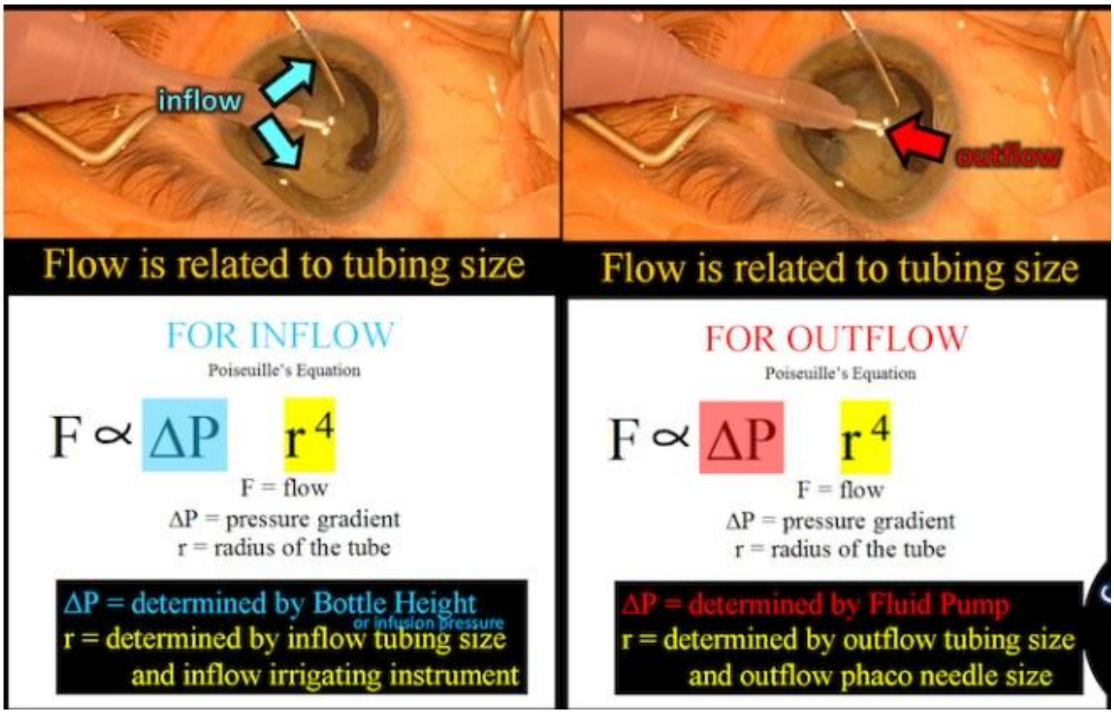
V. Title: **Phaco Fundamentals Part 4: Poiseuille's Equation**

The basic equation that governs all fluid flow during phacoemulsification surgery is Poiseuille's Equation. You already understand this equation if you've ever used a drinking straw to enjoy a milkshake. <u>The larger the bore of the tubing, the less resistance to flow</u>.



We are concerned with the relative relationship and not the exact values, therefore, for simplicity we can simplify this formula. The viscosity of the fluid is relatively constant, as is the length of the tubing. And the values of pi and 8 are constant. This leaves us with a simpler equation.

Flow is proportional to the change in pressure times the radius of the tubing to the fourth power. Because the value for tubing size is exponential, a small change to the radius results in a large change in the relative flow. This is clearly illustrated in a common-sense situation of drinking with straws: With a small-bore straw, very high vacuum is required to achieve relatively little flow. However, with a large bore stray, low vacuum is needed to achieve good fluid flow.

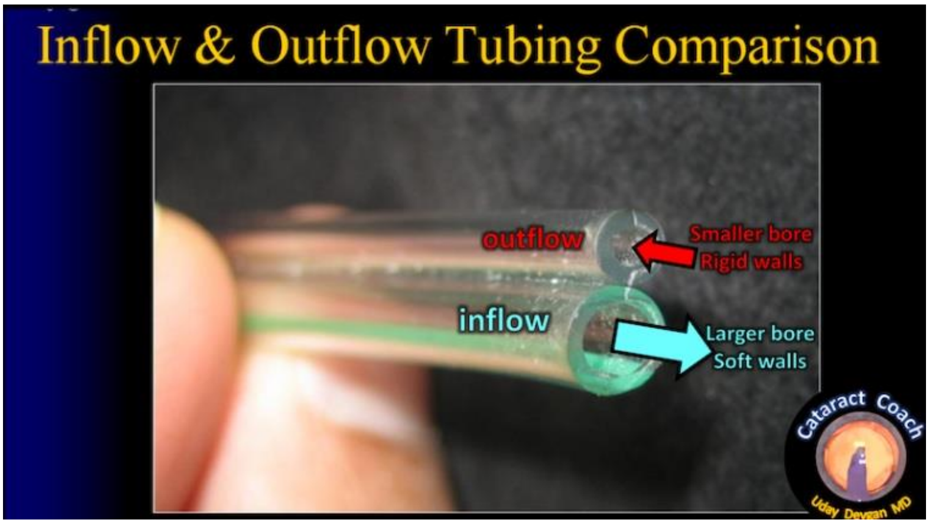


- **Modulating Fluid Inflow**

The source of fluid inflow is the bottle of balanced salt solution that is hanging on the phaco machine. The two factors that determine the rate of inflow are: the change in pressure and the radius of the inflow tubing. The change in pressure can be modulated by raising or lowering the height of the bottle relative to the patient's eye: the higher the bottle, the higher the infusion pressure. The inflow tubing has a large radius in order to maximize the flow and make sure that we keep our inflow greater than the outflow. Similarly, the size of the infusion channel within the phaco probe (or another infusion instrument) is kept as large as possible so as to not cause a bottleneck effect.

- **Modulating Fluid Outflow**

For fluid outflow, there are two sources of fluid leaving the eye: (1) the fluid that is removed via the phaco probe as a result of the vacuum level generated by the fluid pump, and (2) fluid leakage from the incisions. The rate of the fluid outflow via the phaco needle is determined by the radius of the needle and tubing, as well as the change in pressure generated by the phaco machine's fluid pump. The rate of fluid outflow loss via the incisions depends on their size and the relative fit of the instruments within these incisions. Some degree of fluid leakage from the incisions is helpful to allow cooling of the phaco needle and to prevent thermal injury during surgery, particularly in early in the learning stages of phacoemulsification. With the use of advanced phaco power modulations, more experienced phaco surgeons tend to move towards tighter incisions which can give more stable fluidics.

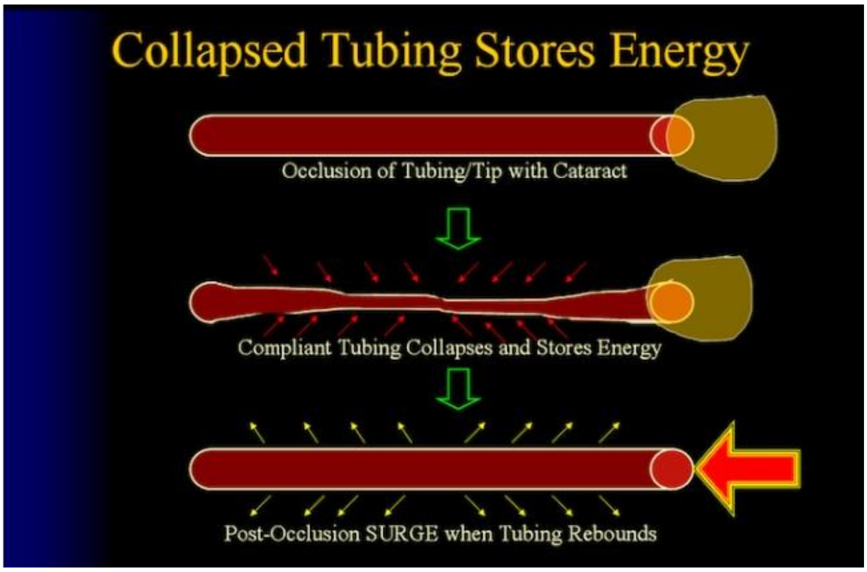


- **Flow Balance & Tubing Compliance**

The composition, nature, and size of the inflow and outflow tubing are different, and this is important for safe and efficient phaco surgery. A surge is a situation when the outflow of fluid from the eye exceeds the inflow, even for just a fraction of a second. When this occurs, the chamber tends to collapse and the posterior capsule can be sucked into the phaco probe in an instant, resulting in a ruptured posterior capsule and vitreous loss. In order to maintain this flow balance, where the inflow is always greater than the outflow, we can use different-sized tubing. If we look at the inflow tubing, we notice that it is significantly different from the outflow tubing.

- **Inflow vs. Outflow Tubing**

The inflow tubing is a large bore with walls that are thin, and the tubing is very flexible. The purpose of this tubing is to provide a high flow of fluid under low-pressure situations. The maximum pressure achieved within this inflow tubing is determined by the height of the infusion bottle, and this level is not very high. The outflow tubing is a smaller bore with thick walls, and the tubing is very rigid and relatively non-compliant. Because the flow varies exponentially with the radius of the tubing, the smaller bore outflow tubing can help ensure that the outflow is less than the inflow. The outflow tubing has rigid, thick walls in order for it to have low compliance which helps to prevent surge. The maximum pressure achieved within the outflow tubing is determined by the fluid pump of the phaco machine and can easily exceed 500 millimeters of mercury.



This high vacuum level can cause a collapse of the outflow tubing if its walls are too thin and of high compliance. When the outflow tubing collapses and then rebounds back to its normal state after the vacuum level drops, this energy release causes an immediate and dangerous surge of fluid out of the eye. This collapse of tubing due to high vacuum levels occurs most commonly during the occlusion of the phaco probe, and then once the occlusion breaks, the tubing rebounds, and the surge occur. **This is called post-occlusion surge and is one of the main causes of posterior capsule rupture during cataract surgery**.

- **Phaco Needle Sizing**

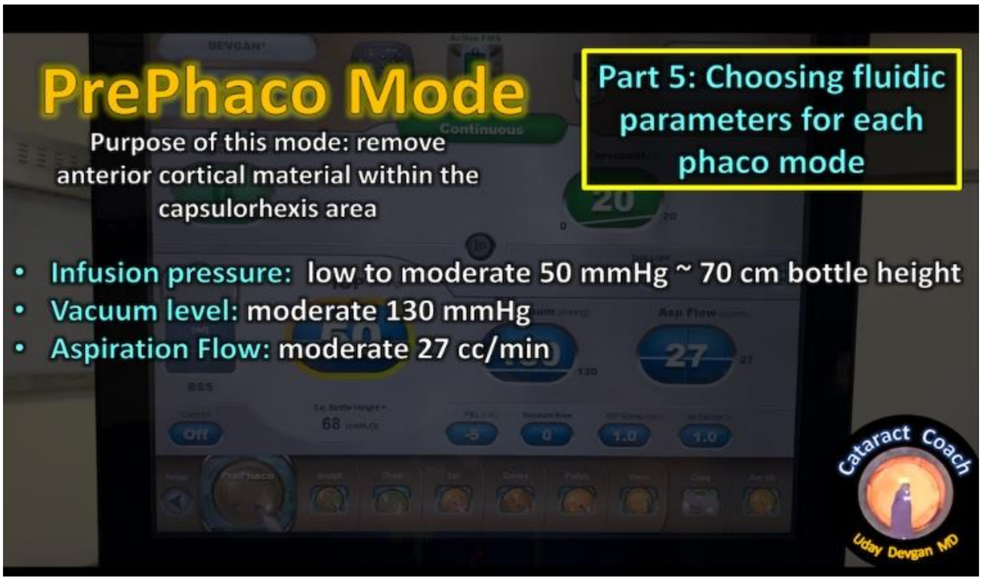
The size of the phaco needle is important for phaco fluidics because it affects the outflow rate. The important thing to remember from Poiseuille's Equation is that the flow is proportional to the radius of the tube to the fourth power. This means that a small change in the size of the phaco needle can result in a very large change in the flow. Comparing two common-size phaco needles, 0.9 mm versus 1.1 mm, with all other factors equal it is surprising to see that the flow through the larger 1.1 mm needle is more than twice that of the 0.9 mm needle. As the needle size decreases, the flow drops dramatically.

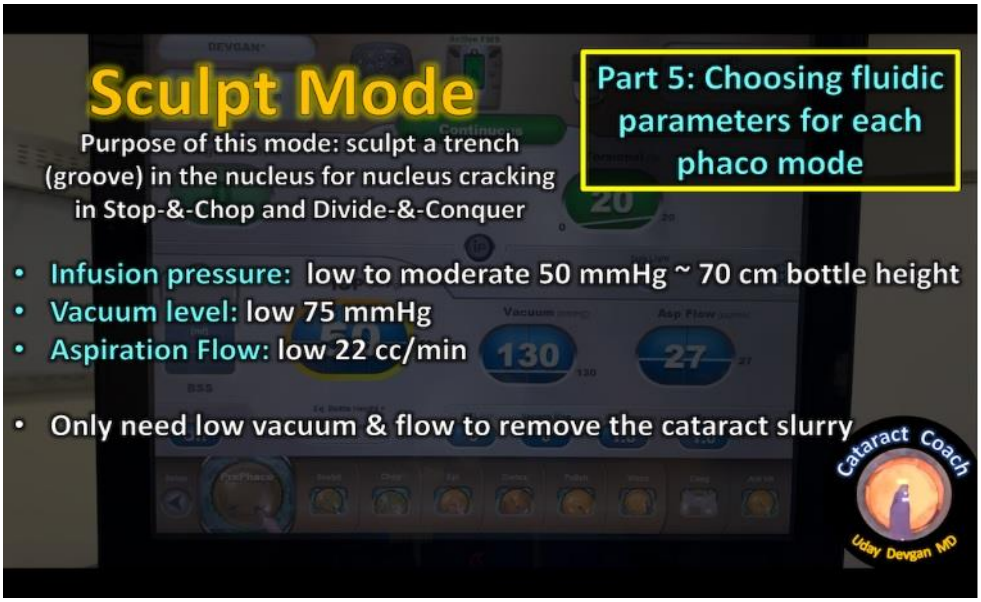
If we switch from a 1.1 mm phaco needle to a 0.9 mm needle, with all other phaco parameters unchanged, the relative flow will decrease by more than half – to 45% of the relative flow through the 1.1 mm needle. In order to achieve the same flow while decreasing the needle size, a very substantial increase in the pressure gradient is required. Once we determine the proper tubing size and phaco needle size for our needs, we can then select the other parameters of the phaco machine. Remember that the tubing size and phaco needle size are definitely variables that play an important role in fluidics. And if you are a surgeon who also performs pars plana vitrectomy surgery, remember that there is a huge difference in fluidics and flow when comparing 20-gauge, 23-gauge, 25-gauge, and 27-gauge instrumentation.

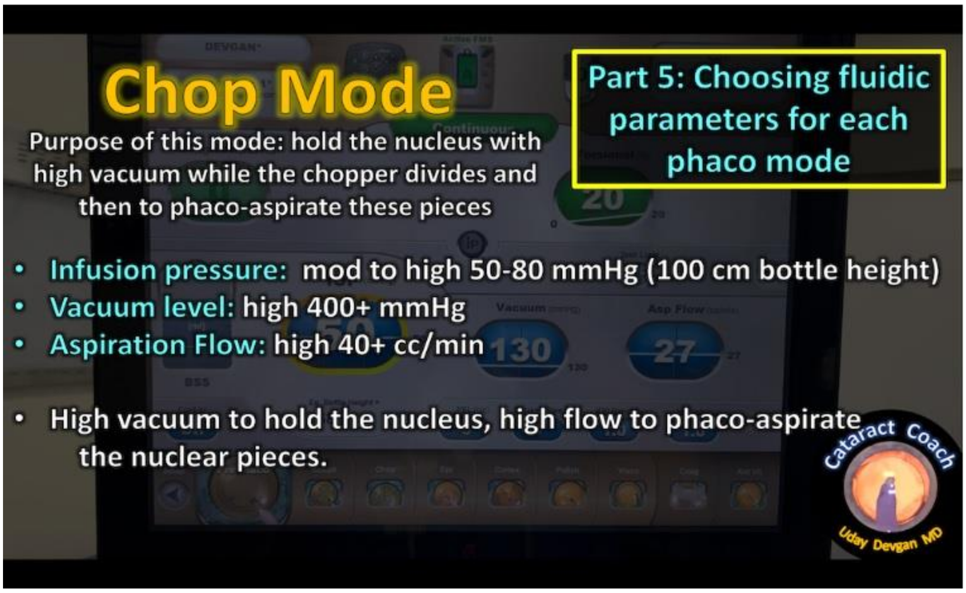
VI. Title: **Phaco Fundamentals Part 5: Choosing Fluidic Parameters**

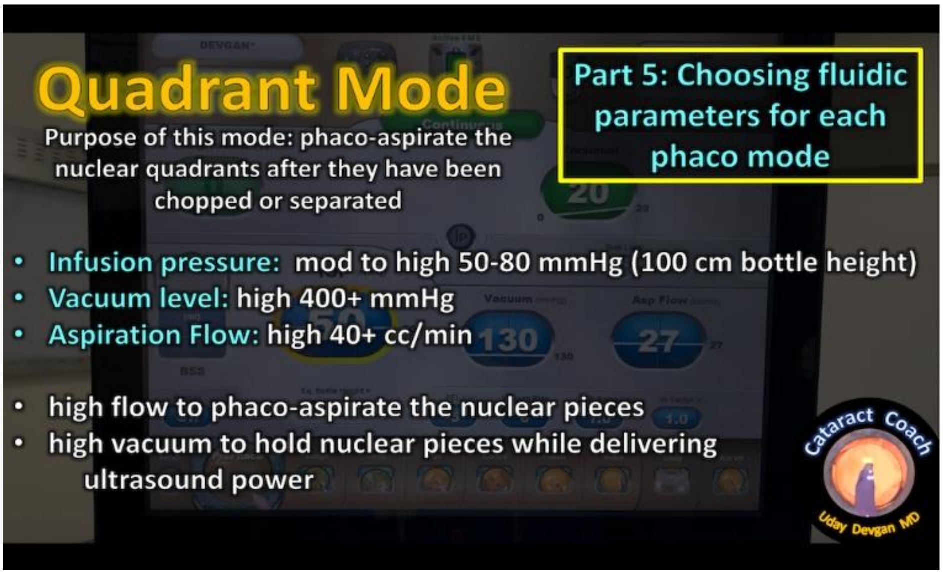
Let's look at choosing specific parameters for each phaco mode. All of these suggested starting points are specific to the machine shown here (Alcon Centurion) and the specific 0.9

mm phaco tip/sleeve as well. Do not use these suggested starting points as an absolute for your surgeries, rather understand the logic behind choosing them. This way you can set your specific machine to optimal settings for your specific style of surgery. While I show many different modes here, remember that my normal, routine cataract surgery uses only three modes; chop, cortex, and Visco removal settings.






Chop Mode
Purpose of this mode: hold the nucleus with high vacuum while the chopper divides and then to phaco-aspirate these pieces
Part 5: Choosing fluidic parameters for each phaco mode
• Infusion pressure: mod to high 50-80 mmHg (100 cm bottle height)
• Vacuum level: high 400+ mmHg
• Aspiration Flow: high 40+ cc/min
• High vacuum to hold the nucleus, high flow to phaco-aspirate the nuclear pieces.
Cataract Coach
Uday Devgan MD


Quadrant Mode
Purpose of this mode: phaco-aspirate the nuclear quadrants after they have been chopped or separated
Part 5: Choosing fluidic parameters for each phaco mode
• Infusion pressure: mod to high 50-80 mmHg (100 cm bottle height)
• Vacuum level: high 400+ mmHg
• Aspiration Flow: high 40+ cc/min
• high flow to phaco-aspirate the nuclear pieces
• high vacuum to hold nuclear pieces while delivering ultrasound power
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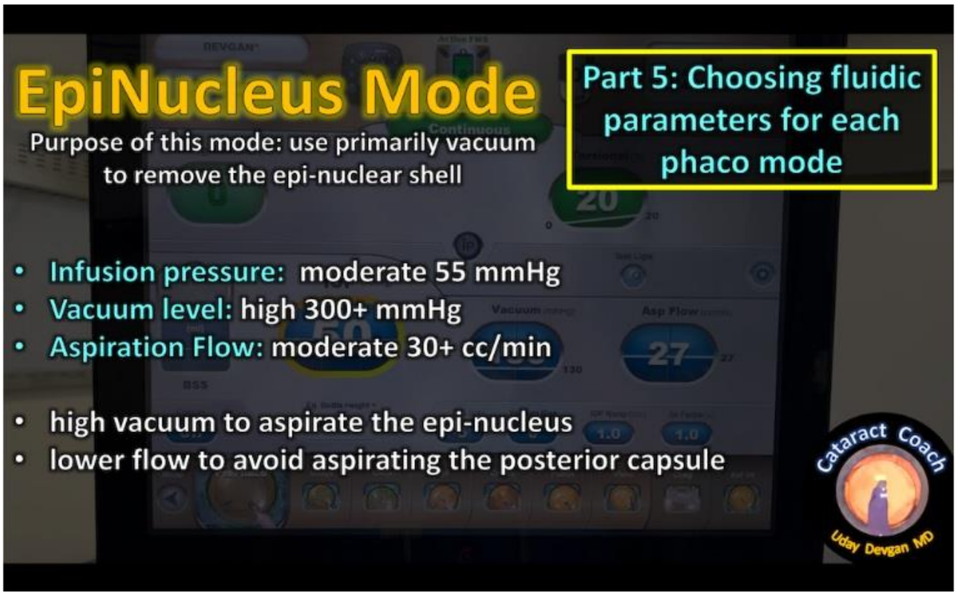
Uday Devgan MD


EpiNucleus Mode
Purpose of this mode: use primarily vacuum to remove the epi-nuclear shell
Part 5: Choosing fluidic parameters for each phaco mode
• Infusion pressure: moderate 55 mmHg
• Vacuum level: high 300+ mmHg
• Aspiration Flow: moderate 30+ cc/min
• high vacuum to aspirate the epi-nucleus
• lower flow to avoid aspirating the posterior capsule
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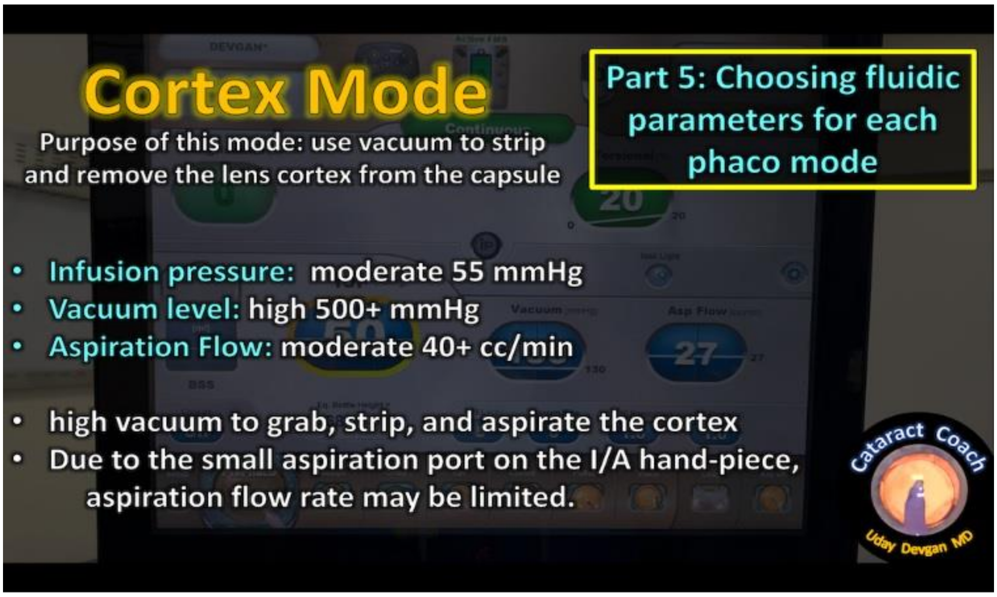
Uday Devgan MD


Cortex Mode
Purpose of this mode: use vacuum to strip and remove the lens cortex from the capsule
Part 5: Choosing fluidic parameters for each phaco mode
• Infusion pressure: moderate 55 mmHg
• Vacuum level: high 500+ mmHg
• Aspiration Flow: moderate 40+ cc/min
• high vacuum to grab, strip, and aspirate the cortex
• Due to the small aspiration port on the I/A hand-piece, aspiration flow rate may be limited.
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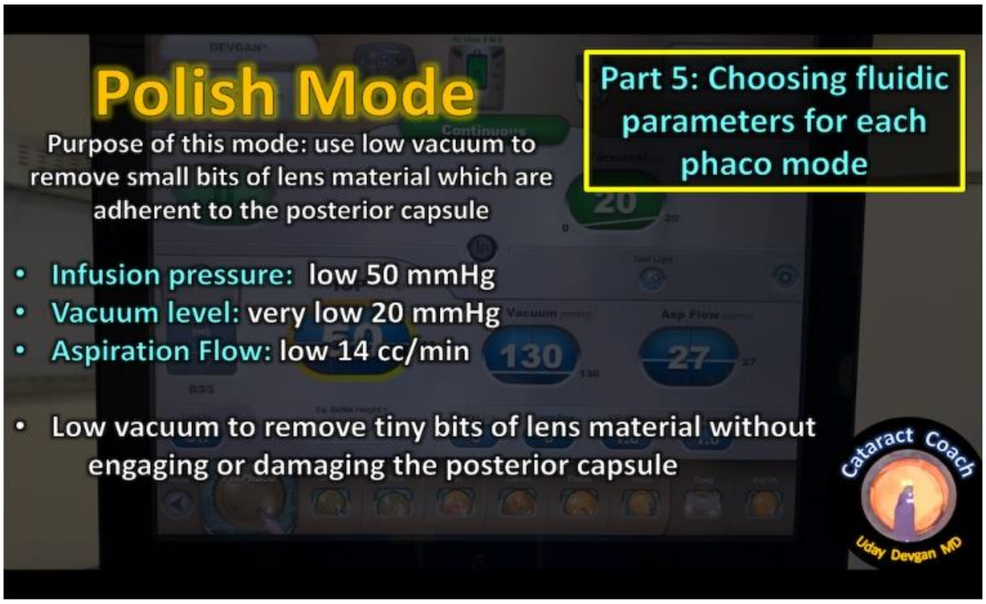
Uday Devgan MD


Polish Mode
Purpose of this mode: use low vacuum to remove small bits of lens material which are adherent to the posterior capsule
Part 5: Choosing fluidic parameters for each phaco mode
• Infusion pressure: low 50 mmHg
• Vacuum level: very low 20 mmHg
• Aspiration Flow: low 14 cc/min
• Low vacuum to remove tiny bits of lens material without engaging or damaging the posterior capsule
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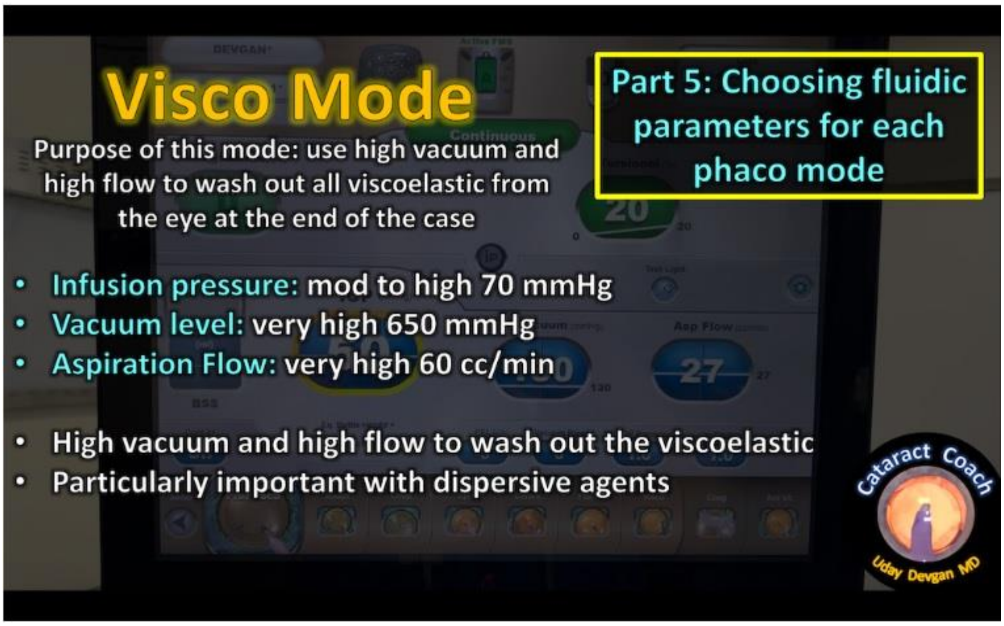
Uday Devgan MD


Visco Mode
Purpose of this mode: use high vacuum and high flow to wash out all viscoelastic from the eye at the end of the case
Part 5: Choosing fluidic parameters for each phaco mode
• Infusion pressure: mod to high 70 mmHg
• Vacuum level: very high 650 mmHg
• Aspiration Flow: very high 60 cc/min
• High vacuum and high flow to wash out the viscoelastic
• Particularly important with dispersive agents
Cataract Coach
Uday Devgan MD

VII. Title: **Phaco Fundamentals Part 6: Adjusting Fluidic Parameters Intra-Op**

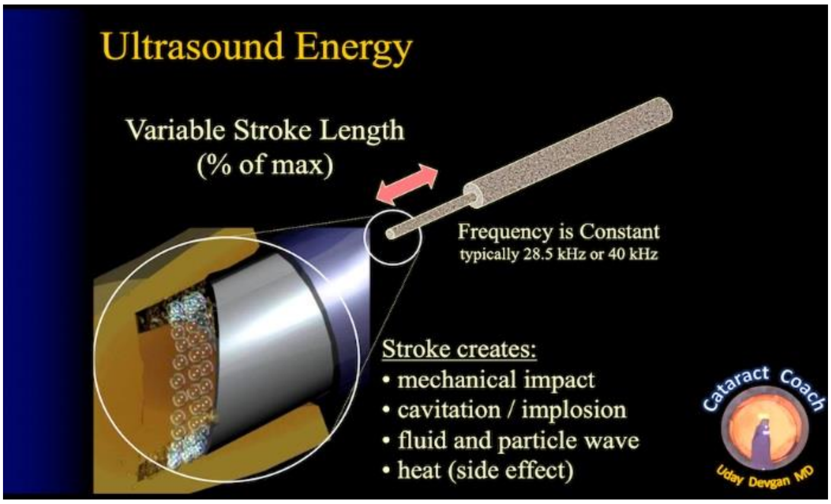
We will learn how to adjust the anterior chamber depth (avoiding too shallow or too deep), limit the fluidic surge that can happen in the post-occlusion state, and increase holding power and followability during nucleus removal.

- Cataract pieces not moving toward phaco tip: increase the aspiration flow rate
- Cataract nucleus falls off phaco tip during chop: increase vacuum level (to increase holding power of phaco tip)
- Post-occlusion surge and AC instability: increase inflow pressure/flow, decrease aspiration outflow, decrease vacuum
- AC too shallow or too deep: adjust inflow pressure/flow, also fix reverse pupillary block

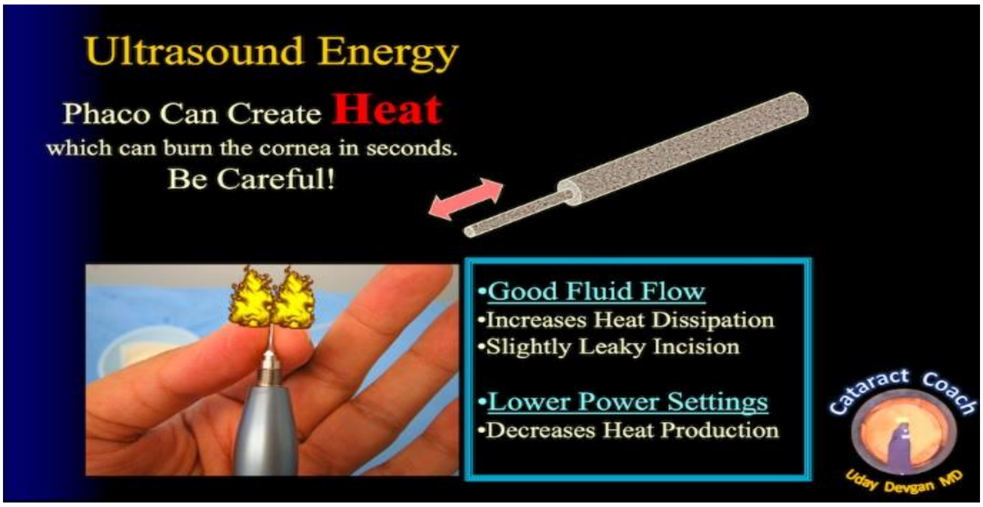
VIII. Title: **Phaco Fundamentals Part 7: Ultrasound Power Modulations**

The phaco ultrasound probe delivers energy into the eye that can be used to break up the cataract to facilitate emulsification and aspiration. It accomplishes this by vibrating at a fixed frequency when the foot pedal is depressed to position three. When we titrate the amount of ultrasound energy we place into the eye, we are keeping the frequency constant but we are increasing the stroke length and therefore, the total amount of energy.

The stroke of the phaco needle creates a mechanical impact as the metal phaco needle hits the cataract material. It also creates cavitation and implosion as a microvoid is created just in front of the phaco needle. A fluid and particle wave is propagated into the cataract material and finally, heat is created as a by-product. It is important to avoid choosing phaco power settings that cause excessive heat build-up as this can burn the cornea and damage the delicate ocular structures.

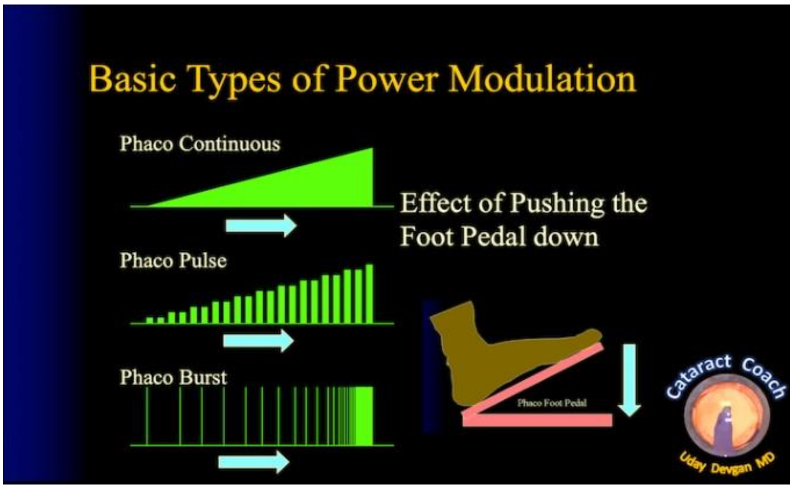


The phaco pinch test is a simple way to determine if your ultrasound power settings are likely to cause an incision burn in the eye. During wet lab testing, program your selected settings into the phaco machine, remove the protective silicone sleeve from the phaco needle, grasp the needle between your fingers, and push the foot-pedal all the way down. If your settings cause excessive heat build-up, the needle will get hot and may even burn your fingers. But **it's better to singe your fingertips than fry your patient's cornea.**

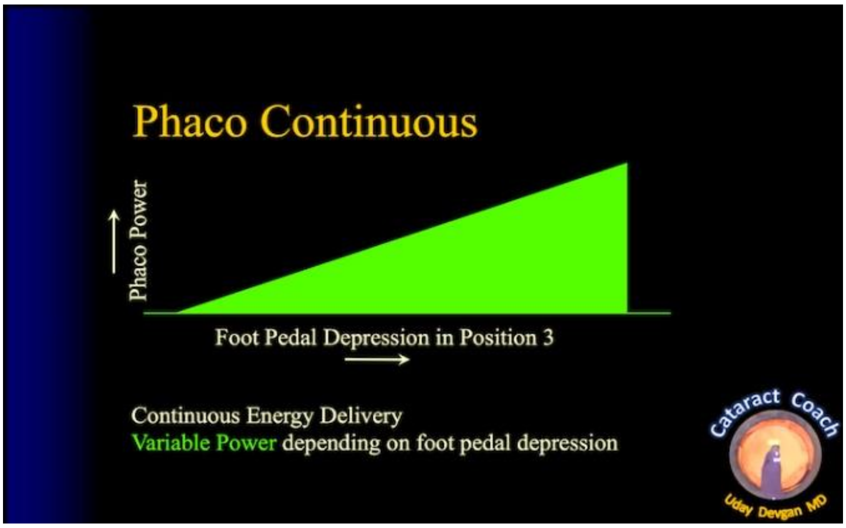


It is important to give as little ultrasonic phaco energy as possible during the cataract surgery as possible. The ultrasonic energy can easily damage the corneal endothelial cells, and excessive phaco energy can cause pseudophakic bullous keratopathy and corneal decompensation. The most important way to decrease the energy is to use a mechanical method of nucleus disassembly such as phaco chop. This is far more efficient than techniques like divide-and-conquer, resulting in less energy delivery as well as a quicker procedure. **To decrease the energy maximally**, we need to decrease the phaco time and we need to decrease the average phaco power. The average phaco power can be decreased by limiting the foot pedal depression in position three or by decreasing the maximum phaco power level on the machine.

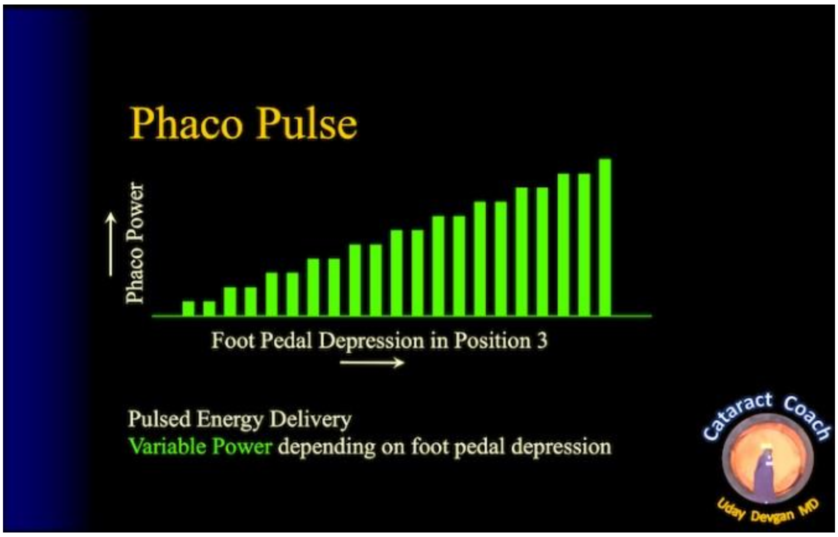
The phaco time can be decreased by only applying the ultrasonic power when cataract pieces are at the phaco tip and are not aspirated by the vacuum forces alone. Additionally, phaco time can be reduced by delivering smaller pulses or bursts of phaco energy instead of continuous ultrasound. This method of breaking up the ultrasonic energy into smaller packets of pulses and bursts is called **phaco power modulation.** With optimized ultrasonic phaco power parameters, it is possible to remove cataracts with a minimal amount of phaco time and energy, giving immediately clear corneas and happy patients.



The basic power settings are continuous, pulse and burst. In the continuous power setting, continuous energy is delivered with variable power depending on how long the foot pedal is depressed. The maximum power setting can be preset and then one has control on the maximum amount of phaco power delivered, ie., the longer the foot pedal is depressed, the greater the phaco power will be.



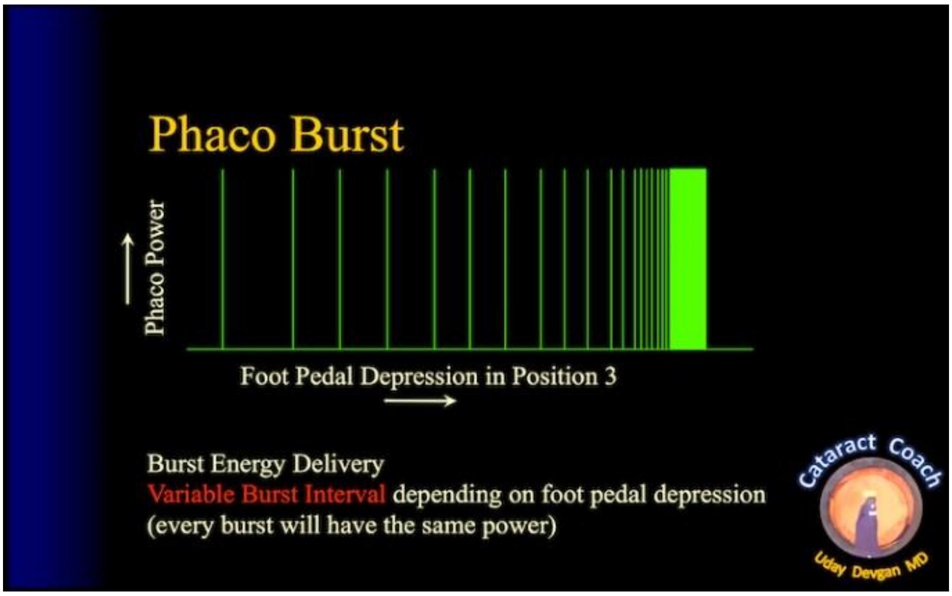
In the pulse mode, the pulses of energy delivered have variable power depending on how long the foot pedal is depressed. The more time it is depressed, the greater the power of each sequential pulse of energy will be. The defining feature of pulse mode is that after each pulse of energy is delivered, there is a period of time in which no energy is delivered between increasing pulses of energy, the "off" period. Alternating between the "on" and "off" pulse, reduces heat and delivers half the energy into the eye.



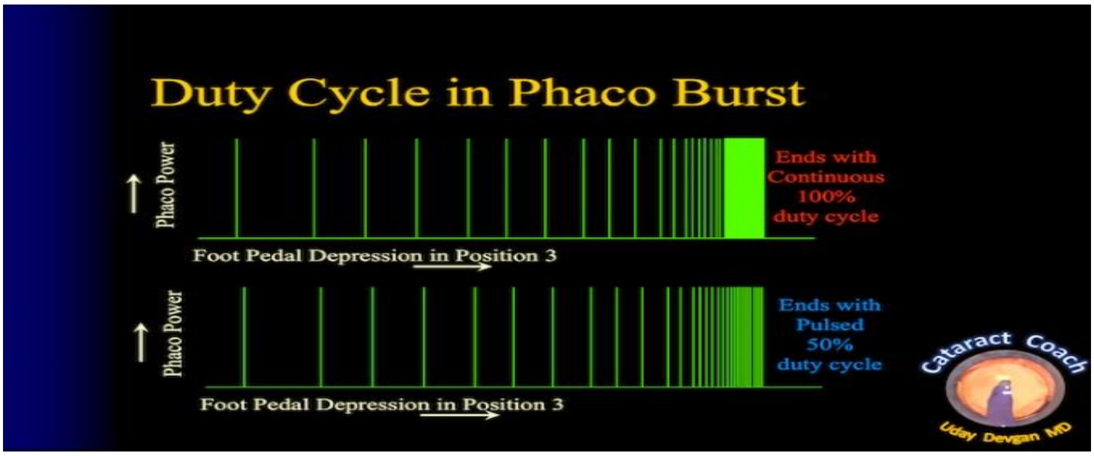
Finally, **in burst mode**, each burst of energy has the same power but the interval between each burst increases as the foot pedal is depressed. The longer the foot pedal is depressed, the shorter the "off" period between each burst will be. As a result, at maximum foot pedal depression, the bursts of energy will become continuous delivery of energy. When referring to modulations of phaco power, the terms "burst" and "pulse" may seem similar, but they refer to two entirely different concepts.

Surgeons are used to the concept of "continuous" phaco energy which is delivered in a linear fashion: as the phaco foot pedal is depressed, the energy level increases. "Pulse" mode simply gives the same linear control of phaco energy; however, the energy is always delivered in pulses. "Burst" mode defines a specific and identical "burst" of phaco energy, then as the foot-pedal is depressed, these identical bursts of energy are delivered more rapidly, until the interval of time between bursts is infinitely small.

Burst mode allows a true phaco-assisted aspiration of the lens nucleus. We use the vacuum and fluidics of the phaco machine to aspirate the cataract and then give small bursts of phaco energy only when necessary. Because we can program these bursts of phaco power to be very short (as quick as a few milliseconds), we can effectively give hundreds of tiny bursts and still total less than 1 second of total phaco time. Because the phaco foot pedal now controls the rest interval between identical bursts, we do not have linear control of the phaco power level. For this reason, it is important to use a lower phaco power setting when using burst mode as compared to pulse or continuous modes. When the foot-pedal is maximally depressed, the rest interval between bursts is zero and the phaco probe essentially delivers continuous energy. We can program our machine to avoid this continuous phaco energy end-point when using burst mode.



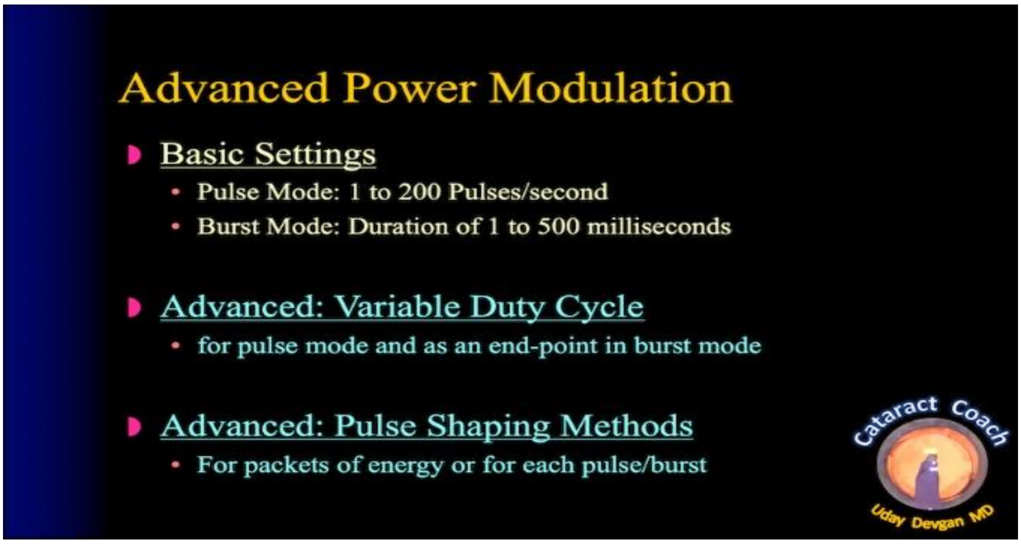
For surgeons using a divide-and-conquer technique of surgery, the foot-pedal can be maximally depressed during grooving, thereby delivering continuous phaco energy to facilitate sculpting of the nucleus. Then to remove the quadrants, the foot-pedal is only partially depressed in position 3 so that only bursts of phaco power are used for segment removal. Finally for the epi-nucleus removal, the foot position 3 is barely entered and just a few bursts of energy are delivered for removal of the softer cataract portions.



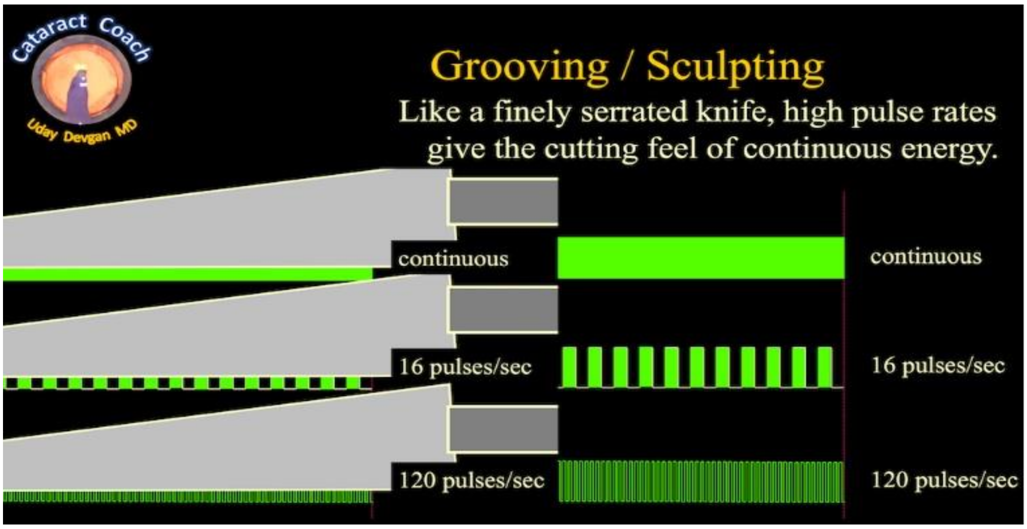
Most phaco machines have two settings for burst mode: single burst and multiple burst. Single burst delivers just one single burst of energy, for burying the phaco probe into a nucleus for chopping. I do not ever use this mode, but instead prefer multiple burst mode because I can still deliver just one single burst by barely entering foot-position 3 and I still have the ability to deliver many more burst and varying intervals with further foot-pedal depression.

IX. Title: **Phaco Fundamentals Part 8: Variable Duty Cycle**

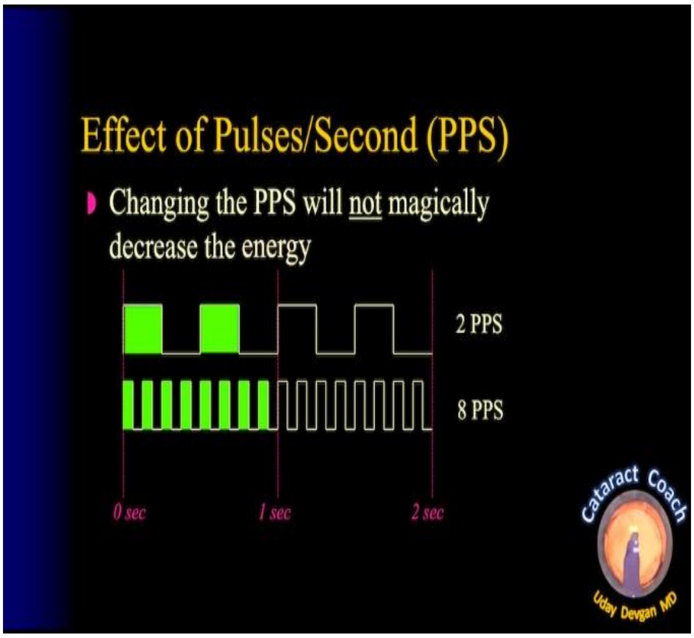
The range of programmability of the pulse and burst phaco settings has expanded considerably. While previous generations of phaco platforms had pulse rates of up to 20 pulses per second, the newer generation machines have the ability to deliver up to 200 pulses per second. Similarly, the older machines had burst widths as narrow as 30 milliseconds.

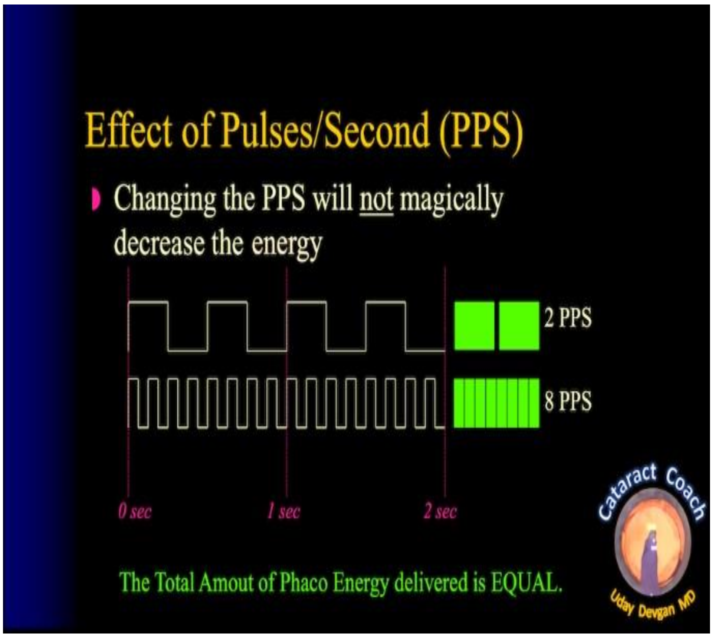


The advantage of this upgraded range of programmability is the smoothness and precision of power delivery. With the standard settings in pulse mode, where each pulse is as long as each rest period, the pulse mode can deliver good cutting power with half the energy of continuous phaco energy. The more pulses per second we can give, the smoother the power delivery will be – very similar to serrations on a knife.



If we want to harness the sculpting and cutting ability of the phaco hand-piece for grooving of the cataract nucleus, it makes sense that a smooth blade knife would cut well. A coarsely serrated knife with large widely spaced serrations would not cut as smoothly. However, if we use a very finely serrated knife, it would likely cut the best of all. Using a very high pulse rate of 100 or more pulses per second results in the cutting ability of a very finely serrated knife while delivering half of the energy of continuous phaco power.



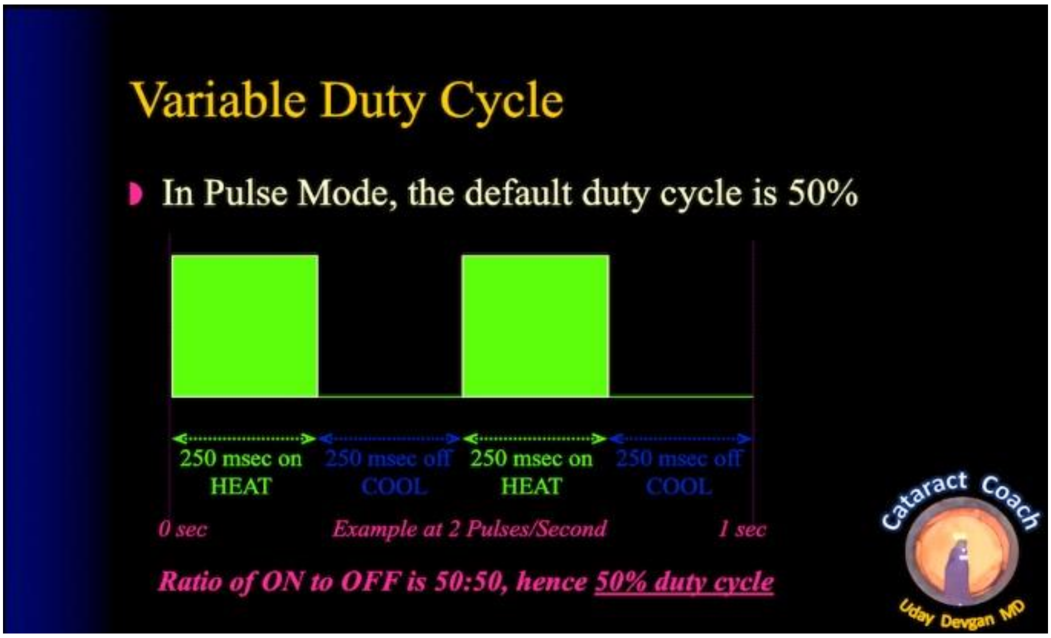


Hyper settings in burst mode allow finer and more precise delivery of bursts of phaco power. If we use continuous phaco energy mode and try to use our foot to deliver small bursts of phaco power, the best we can do is about a half-second of energy per pulse, which is 500 milliseconds. Using the newer hyper settings we can set a burst mode as small as 4 milliseconds, which is 100 times finer and more precise than using manual control by the surgeon.

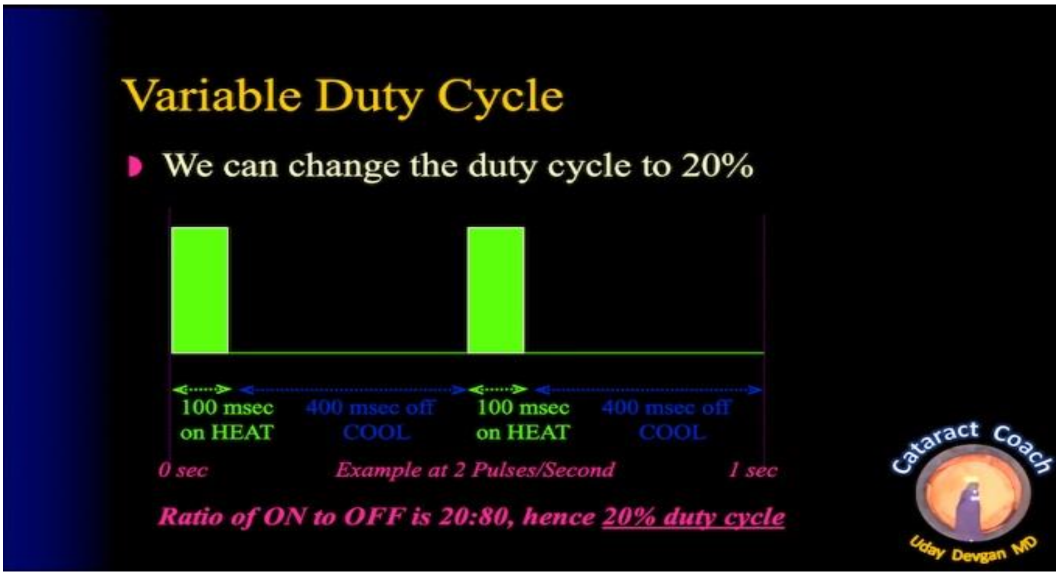
Modern surgery is primarily phaco-assisted aspiration of the nucleus. The majority of the forces that are used to remove the nucleus from the eye are fluidic forces – the flow, aspiration, and vacuum forces. The ultrasonic power delivery is there to assist the fluidics once a denser piece of the nucleus is encountered. If we are using burst mode, with a very fine burst width, then as the pedal is depressed further in foot-position 3, the rest interval between bursts decreases until the burst width and rest interval are equal, resulting in a 50% duty cycle. The effective number of bursts per second increases as the rest interval decreases and using a burst width of 5 milliseconds and allowing 5 milliseconds of rest between each burst, the maximum number of bursts per second is 100. (Math: 1 second / 10 millisecond cycle = 100 bursts per second). This results in being able to effectively control the duty cycle and burst rate per second at the same time via the foot pedal.

For surgeons who wish to continue to perform their standard technique of phaco-emulsification, simply changing from continuous phaco power to a hyper pulse rate of 100 pulses per second will allow them to cut the energy delivery in half. This halving of the ultrasound energy will result in less endothelial cell damage, less heat production, and clearer corneas, and sharper vision immediately post-op. For surgeons who perform the divide-and-conquer method of nucleus phaco, make the switch to a hyper pulse mode and you will immediately perform better surgery without a change in your technique.

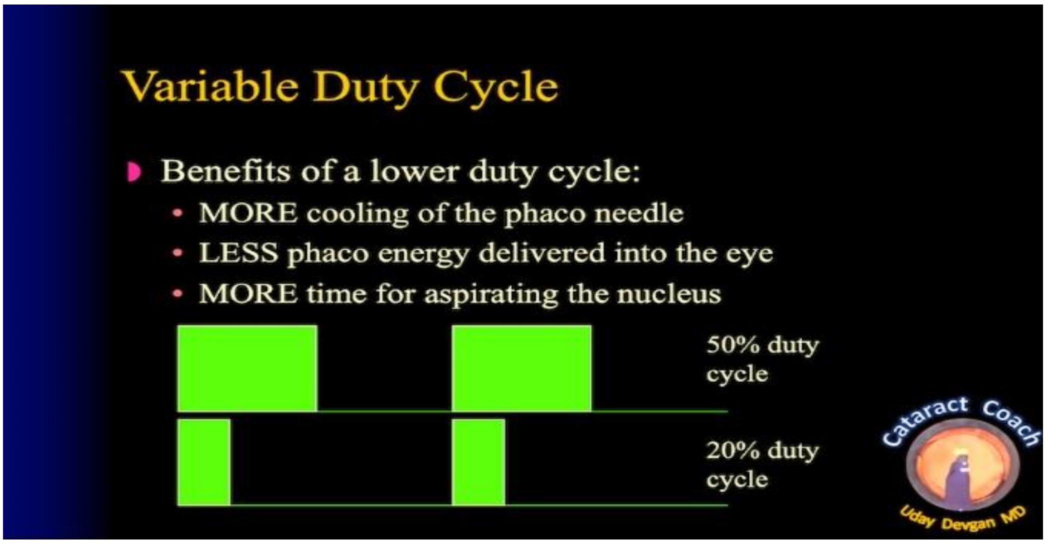
Changing the number of pulses per second does NOT change the amount of power delivered into the eye. Whether we give 2 pulses per second or 8 pulses per second note that the total energy, as represented by the green blocks is the same. The same applies when we compare 10 pulses per second to 100 pulses per second. The reduction in the amount of energy delivered is due to the ratio of the on: off pulses, which is known as the duty cycle.



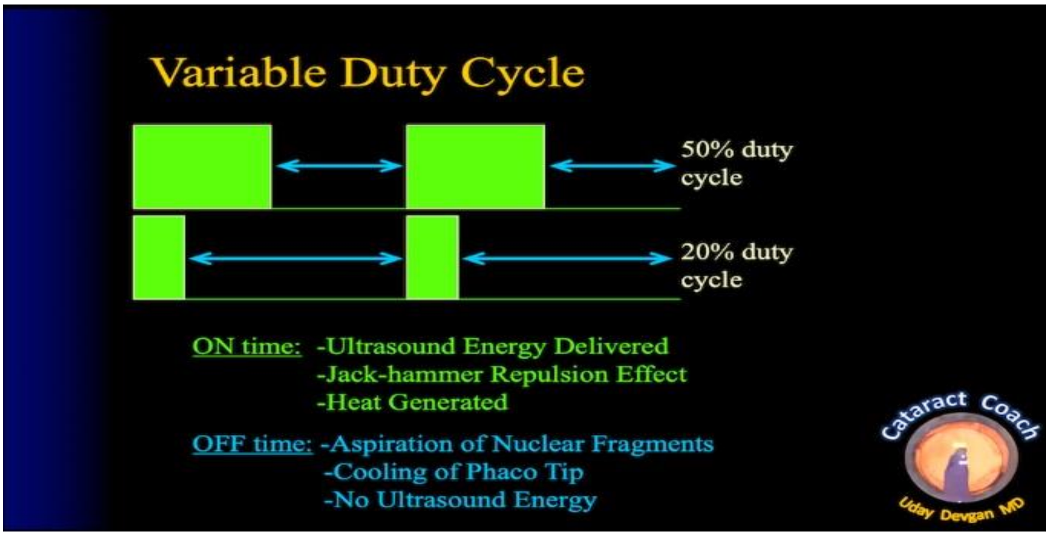
To program in a change in this ratio, **there are two distinct methods: entering a new duty cycle or direct pulse programming**. For example, if I am using 10 pulses per second and I'd like to slightly reduce the ultrasound energy, I can decrease it from a 50% duty cycle to a 40% duty cycle. This can be done by dropping the duty cycle ratio as seen on the control panel of the phaco platform. Alternatively, I can delineate the specific on and off periods for each cycle, with an on time of 40 milliseconds on followed by 60 milliseconds off, I will achieve the same result – a total cycle time of 100 milliseconds, which corresponds to 10 pulses per second, with a ratio of the on:off time resulting in a 40% duty cycle.



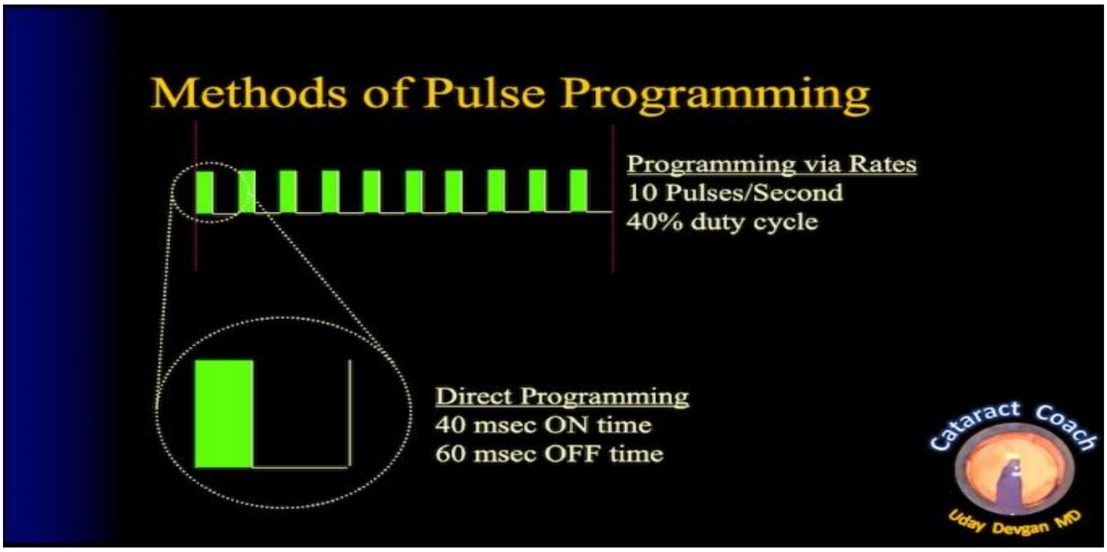
In the pulse mode, the default duty cycle is 50%. For instance, the pulse is on the "on" position 250 msec and "off" for 250 msec. The benefit of the new power modulation software is that the duty cycle can be changed for example to 20% which results in 10 msec on, 400 msec off giving a ratio of 20:80. We can then harness the benefits of a lower duty cycle which results in longer cooling time for the phaco needle, thus decreasing the amount of phaco energy delivered to the eye. In addition, during the extended "off" time, no energy is delivered and nuclear fragments can be easily aspirated.



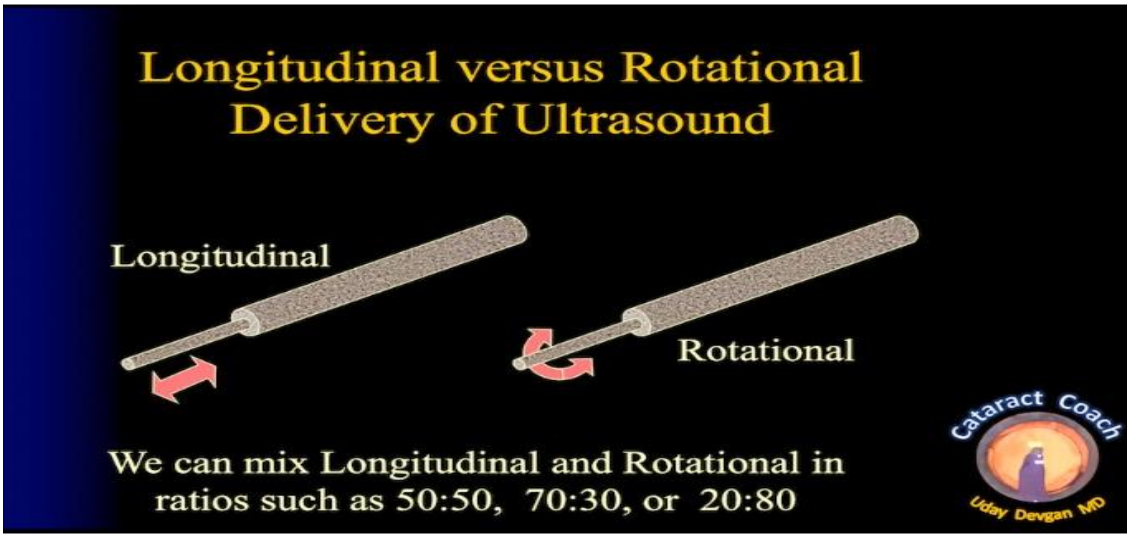
<u>When do we want higher or lower duty cycles?</u> **The answer depends on the phase of surgery**. For sculpting the nucleus, such as with the technique of divide-and-conquer, we need to deliver sufficient energy to be able to cut the grooves. This requires a duty cycle of about 40 to 60%. Once we have the grooves placed in the nucleus and we have achieved cracking resulting in quadrants, we can use a lower duty cycle during the phaco-assisted aspiration of the quadrants. For this quadrant removal, a lower duty cycle of 20 to 40% can be used since the principal force for suction is the fluidics and not the ultrasound.



Using the variable duty cycle programming allows the surgeon to deliver just the right amount of ultrasound energy during each phase of surgery. The concept to remember is that a higher duty cycle results in better cutting power but increased heat generation and more energy-related damage to the corneal endothelium. Using the lower duty cycle allows more fluidic aspiration of nuclear fragments while minimizing heat and phaco power, resulting in clear corneas immediately after surgery. And we all know that clear corneas on post-op day one makes for good visual acuity and very satisfied patients.



Some phaco machines give the choice between **longitudinal ultrasound power** (which is in a back-and-forth linear motion) and **rotational ultrasound power** (which is in a circular, elliptical, or torsional pattern). These two modes can also be mixed together to give different ratios.



X. **Title: Phaco Fundamentals Part 9: Longitudinal & Torsional Ultrasound**

Ultrasonic vibrations are traditionally delivered in a **forward-and-back longitudinal manner**. We can also deliver these vibrations in a **circular** manner and these often go by the names of **torsional, elliptical**, or other descriptors. During ultrasound delivery, we can adjust the amount of each type of energy given to come up with a balance that is ideal for our step of surgery, the technique, and the type of cataract. While all phaco machines will have longitudinal ultrasound energy delivery, only the newer models from some companies will have other forms such as torsional. The longitudinal energy can be delivered as continuous, pulse, or burst.

Watch this video as an example: https://www.youtube.com/watch?v=lPMQM4pOPyY

XI: **Phaco Fundamentals Part 10: Sample Phaco Settings**

This video shows specific starting settings for all steps of cataract surgery:

https://www.youtube.com/watch?v=1TcNuFMXIV0

Remember that these are starting points only and that the fluidic settings are specific to this particular phaco needle and tip. If you are using a smaller phaco tip with less fluid flow, then you will need to adjust the settings. This video shows a 2.75 (or 2.8) mm phaco tip but if you are using a 2.2 mm phaco tip then some changes will be needed: you will have less flow and therefore you should decrease the aspiration flow rate (lower the outflow) and increase the infusion pressure/bottle height (raise the inflow). You will also need higher vacuum levels if the bore of the needle is smaller.

If you are doing a case with a smaller anterior chamber, then more inflow pressure would be helpful. If the chamber is too deep, then lowering the inflow pressure is suggested. If the nuclear particles don't flow towards the phaco tip then increase the aspiration flow rate. If the phaco probe doesn't hold the nucleus well for chopping, then increase the vacuum level. If the ultrasound energy is too low to effectively bury the phaco tip for the chopping technique, then increase the power level.

20. Title: **6 Mistakes that Beginning Cataract Surgeons Make**

There are quite a few pitfalls in learning cataract surgery, and I have found that the same types of mistakes tend to be made early in the learning curve.

Mistake 1: Not knowing your patient inside and out

Remember that it is not "just a surgery" but rather it is an invasive procedure that will change the way your patients see the world, every waking moment, for the rest of their lives. Being prepared ahead of time allows you to have a smoother and safer surgery. If the patient has a white cataract, you will know ahead of time to have the trypan blue dye ready. If the patient has a pulmonary disease with orthopnea, you will need to adjust the bed position as well as your phaco machine settings. If the patient is a poorly controlled diabetic, then postoperative healing can be compromised and the complication rate can be higher. You must know the complete ophthalmic history of your patients as well as their systemic conditions that can affect the surgery and the outcome.

Mistake 2: Not setting up the equipment ahead of time

The microscope needs to be set for your pupillary distance and refraction. The stool and foot pedals should be positioned ergonomically with enough clearance from the patient's bed. The phaco machine must be programmed with your individual settings for your specific technique. You can even designate different settings for dense cataracts vs. softer ones. Your patient list and orders for the day need to be neat and orderly in order to ensure that you will be placing the correct lens in each patient.

Mistake 3: Poor draping and positioning of the patient

The patient should be positioned so that the iris is parallel to the floor. This will allow better visualization and easier access while keeping the patient comfortable. The head can be positioned so that it is closer to the surgeon to avoid having to reach it. Some surgeons elect to temporarily tape the patient's head to the operating room table for added security. The draping of the lashes away from the surgical field is critical because it is the typical source of the bacterial flora that can cause endophthalmitis. In addition, by using a plastic drape around the lid margin, the oil-producing glands can be blocked from contaminating the ocular surface.

Mistake 4: Making a poorly constructed incision

The incision is more than an entry site for cataract surgery — it is a large factor in the fluidic balance of the eye, the astigmatic effect of surgery, and the barrier to postoperative infection. Care must be taken to make the incision with the proper dimensions to match the phaco tip sleeve. For my resident surgeons, **I recommend making the tunnel length of the incision about 2 mm while barely nicking the limbal vessels for the best long-term sealing.** Incisions that are purely in the clear cornea should be avoided because they are completely avascular, which means that they will not permanently seal in the future. A poorly constructed incision will also lead to instability of the anterior chamber during phacoemulsification. This will increase the risk of surge and rupture of the posterior capsule, resulting in a complication that can significantly reduce the visual potential of the eye.

Mistake 5: Not keeping the eye in the primary position and not pivoting

Once you have instruments in the eye, the position of your hands and fingers will determine if the eye is in the primary position looking straight into the microscope or if it is being pushed into the nasal canthus. The surgeon controls the eye position through hand movements and the ability to pivot within the incision. Think of our eye instruments primarily as pivoting tools. In a rowboat, the handle of the oar will move only about 2 feet, but the paddle end, which is in the water, will move 8 to 10 feet or more due to the pivoting action. Our instruments are like this in reverse: We move the long handles of our instruments 30 mm outside of the eye, and then using the incision as our pivot, the tip of the instruments moves 1 mm or less inside of the eye.

Mistake 6: Failure to learn from every surgery

Athletes review footage of their performance so they can learn from their mistakes and figure out ways of improving. Surgeons should do the same, and with modern digital video equipment, it is possible to record all surgeries that are done. These videos should be studied later with a focus on what could be done better. You should always aim to improve your surgical skill, even after having done thousands of surgeries. Also remember that it is more so about judgment, skill, and finesse rather than a specific technique because that aspect will change in the future. The way we do surgery today will certainly evolve in the years to come, and we need to keep up with the latest advances. Finally, make sure you see your own post-operative patients so that you can see the direct effect of the surgery and their healing response.

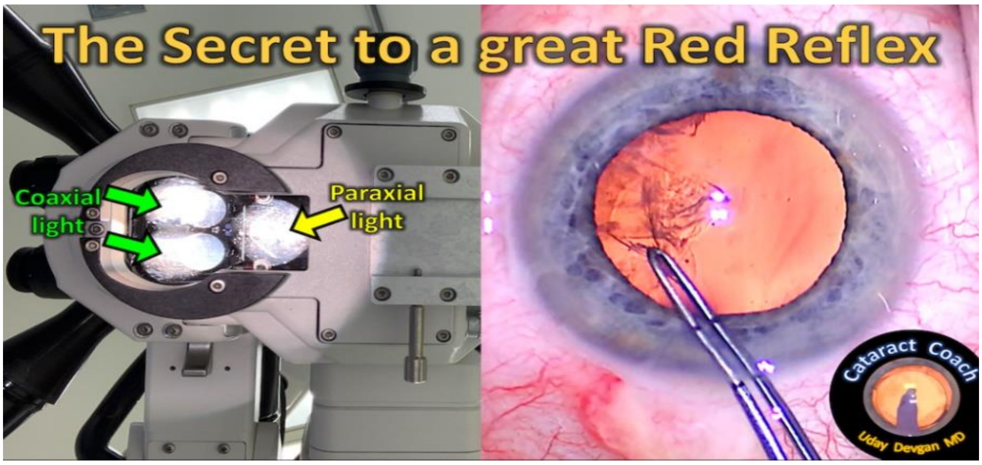
21. **Title: Do you really want to learn surgery?**

This is one of the most important videos that I have ever made. If you only watch one of my videos a year, it should be this video.

https://www.youtube.com/watch?v=O0UYf4hxdag

For all surgeons, but particularly for beginning surgeons, you need to be your own toughest critic. Be tough on yourself. Hold yourself to a higher standard. Don't seek empty praise and sugar-coated comments from your senior colleagues, attending surgeons, and professors. Rather, you want to seek true constructive criticism so that you can become better than you are today. Your goal is to be the best version of yourself. And you can do it, as long as you have the right attitude.

22. **Title: Optimizing the Red Reflex during Surgery**

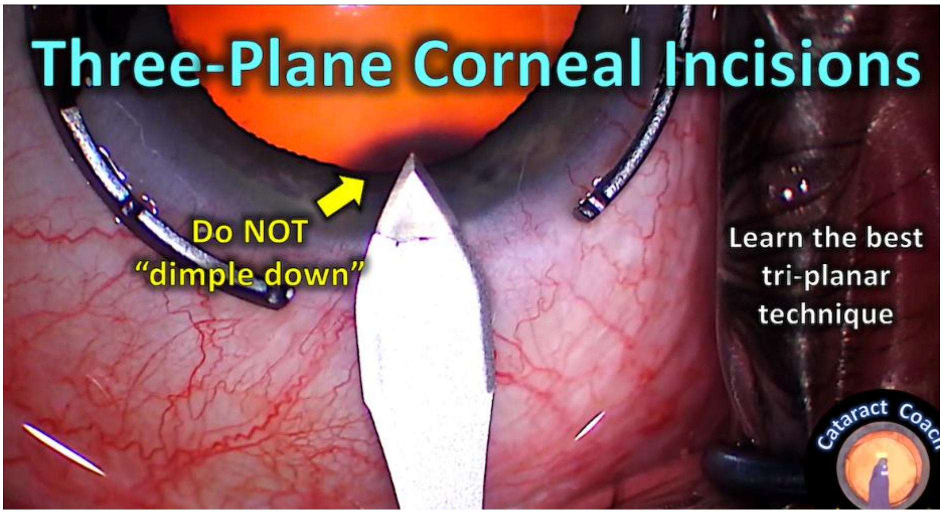


Illumination through the ophthalmic microscope is important for visualization during cataract surgery. We use a combination of both coaxial and paraxial light sources to light up our surgical field. The coaxial lights are aligned co-axial to our oculars, hence their name. The paraxial light is just next to the path of our oculars, usually set a few degrees to the side. It is the balance of the coaxial to paraxial lighting that determines the best red reflex.

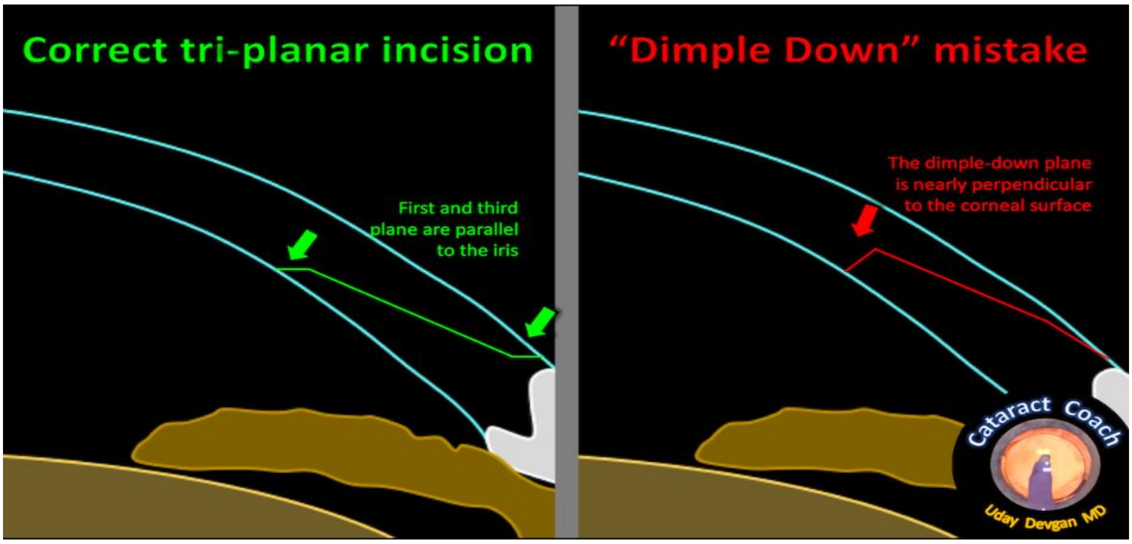
Keep in mind that with lens opacities that block light from entering the posterior segment, such as in a white or brunescent cataract, the red reflex will be diminished, even with the coaxial setting at its maximum. In these cases, <u>if the paraxial illumination does not give enough of a view for the capsulorhexis, then the use of Trypan Blue dye is recommended to stain the anterior lens capsule.</u>

When we are operating, the ratio of coaxial to paraxial lighting is typically between 25;75, and 50:50 to give the best balance. For filming videos for surgical teaching, we must skew this ratio for more coaxial lighting, with a ratio of about 75:25 because the camera sensors are not as sensitive as the surgeon's eyes.

23. Title: Three-Plane Phaco Incisions (Tri-Planar)



Making the phaco incision is one of the most critical steps in cataract surgery. A well-constructed incision will seal without leaks, induce a predictable amount of astigmatism, and will provide excellent access to remove the cataract and insert the IOL.



In the correct tri-planar incision (green diagram above), there are three planes when we look at the incision in the side profile: the incision starts parallel to the iris then the angle changes to go into the corneal stroma and create the desired tunnel length. Then the blade is brought parallel to the iris again in order to enter the anterior chamber.

In the "dimple down" mistake (red diagram above), the initial plane starts out very shallow, then the angle is shifted to achieve the desired tunnel length. Finally, to enter the anterior chamber, the surgeon must abruptly change the angle to enter the anterior chamber. This "dimple down" technique will result in an imbalanced incision with a thin roof and thick floor, which will look like a chevron when viewed at the slit lamp or surgical microscope.

24. Title: Take Pride in your Cataract Surgery Signature

One year or even one decade after your cataract surgery, anyone who examines the patient with a slit-lamp microscope will notice these three things: **(1) the capsulorhexis, (2) the**

incisions, and (3) the position of the IOL. Take time to master each of these steps to produce the best visual results for the patients and also to perfect your surgical signature. Everything else in the surgery including the Nucleo-fractis technique, the ultrasound energy, the fluidic volume used, the viscoelastic, and even the post-operative inflammation, is transient and will not be seen years later.

- **Measure the capsulorhexis to ensure the correct size and placement**

The capsulorhexis is important for successful cataract surgery because it gives the capsular opening strength during cataract removal and allows for stable, long-term positioning of the IOL. We can create the capsulorhexis using forceps or a bent needle (cystotome) and we aim to make it round, well-centered, and about 5 to 5.5 mm in diameter in most cases. For these manual techniques, it is helpful to measure first to get an idea of the appropriate size prior to starting the capsulorhexis. We can also use automated devices such as a femtosecond laser or units which use an electrical discharge, to create a consistent capsulotomy. Most of the time, I use forceps, which have been marked at 2.5 mm and 5.0 mm from the tip, to guide me. At the beginning, prior to starting the capsulorhexis, I measure the anticipated position and diameter. Then I start the tearing of the anterior lens capsule and then stop and re-measure just to be sure. Then after completion of the capsulorhexis, a final measurement is done to confirm the correct diameter (Figure 1A & 1B).

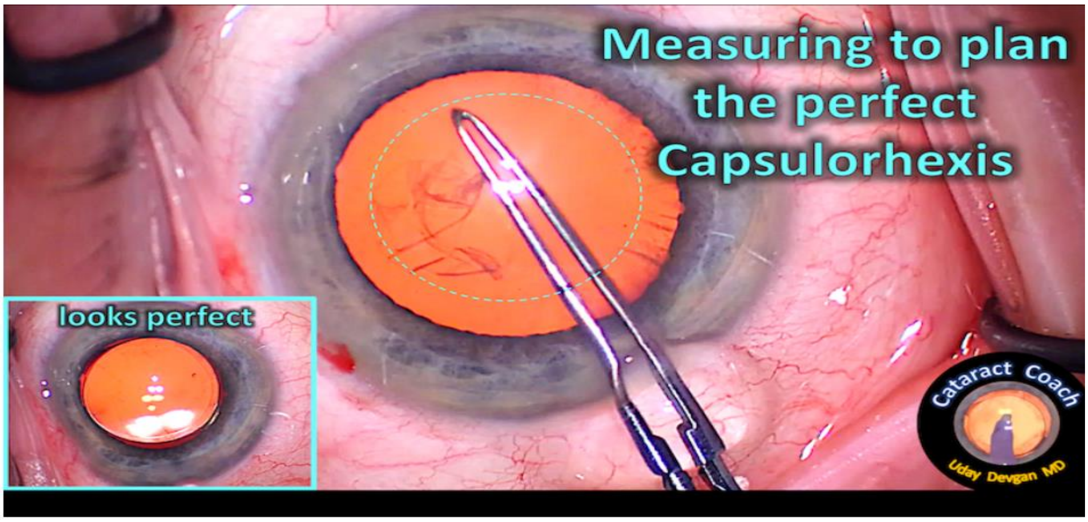


Figure 1: (A) We use the forceps to estimate the ideal position and size of the capsulorhexis.

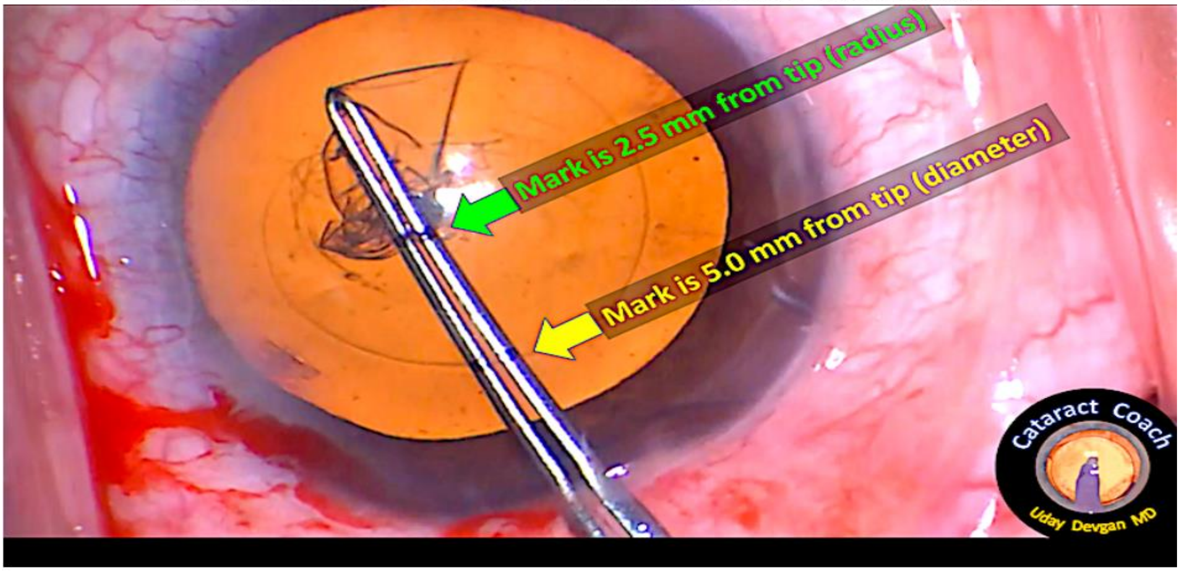


Figure 1: (B) then during this step, we can use the marks on the forceps tips to ensure the correct radius and diameter of our opening.

Many surgeons use the iris or pupil size as a guide for capsulorhexis creation — but you should not. Do not fall into this trap. Look at the picture in Figure 2 — both eyes have the same model lens with a diameter of 6.0 mm and both have capsulorhexis which is about 5 mm in diameter, giving an excellent overlap of the optic. But the eyes are very different — the anterior segment size, the white-to-white measurement, and the pupil dilation are all markedly different. In the large myopic eye, using the iris as a guide would have resulted in an overly large capsulorhexis which would not have held the IOL optic securely. This is the reason why I use marks on my forceps.

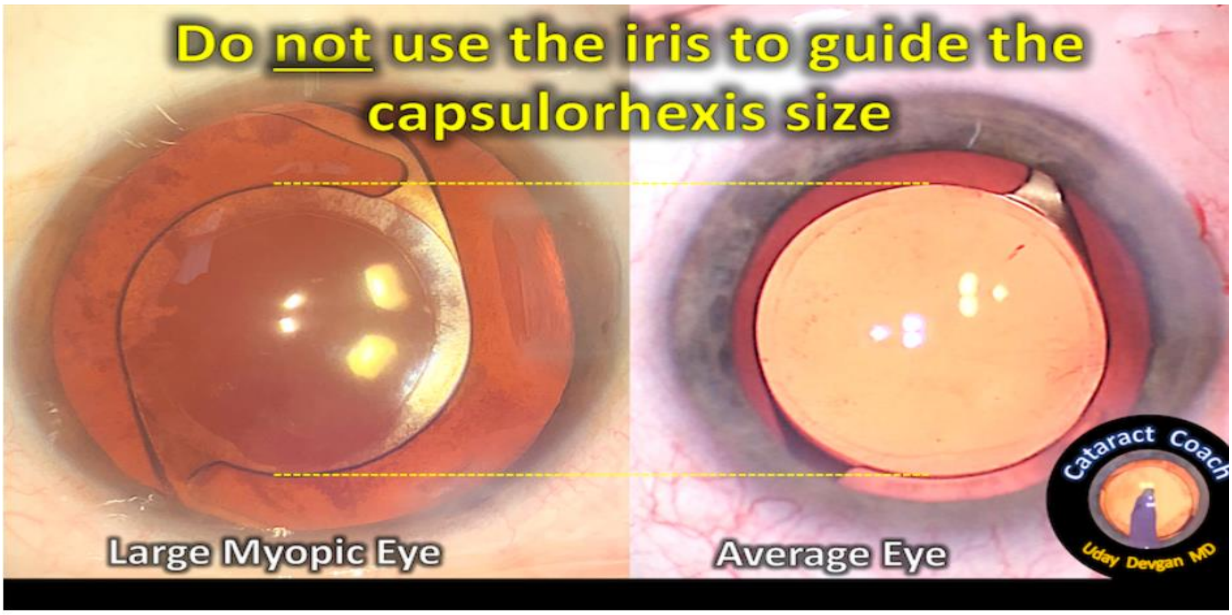


Figure 2: Do not use the iris to guide the capsulorhexis size because dilation and anterior segment size will vary between patients. The large myopic eye (left) has a bigger capsular bag and dilation compared to the average emmetropic eye (right).

Craft the phaco incision so it has a balanced architecture — it will seal better and induce less astigmatism

The phaco incision is critical to the success of cataract surgery. It gives us controlled access to the cataract, assists in maintaining fluidic balance, induces minimal astigmatic changes, and seals securely. A well-constructed incision makes the surgery safer and the recovery quicker. A good incision will have an excellent balance between the roof and the floor and appropriate architecture. It will seal well and securely with minimal astigmatic effect.

If the incision has too long of a tunnel length, it starts out very shallow with a thin roof and then the surgeon abruptly changes the angle to enter the anterior chamber. The result is a bad incision with too thin of a roof and too thick of a floor which does not seal well. (Figure 3)

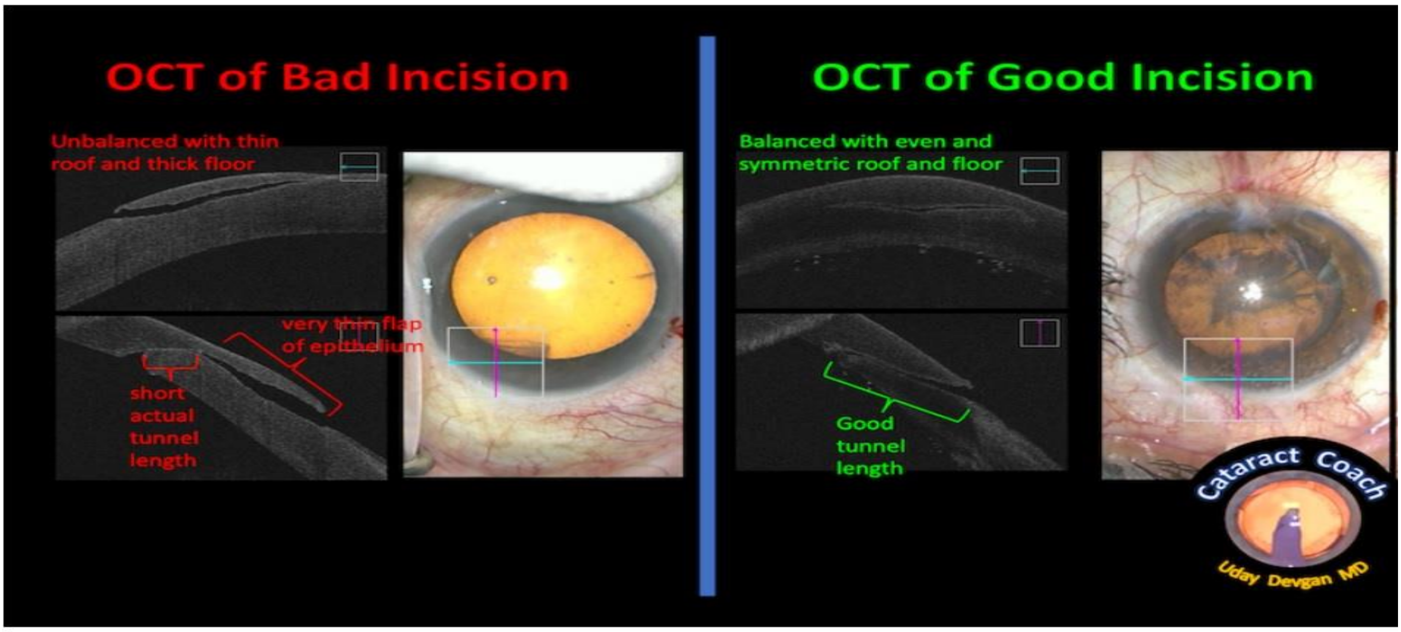


Figure 3: The phaco incision should be constructed with proper architecture for best healing and minimal astigmatic effect.

The angle of approach of the keratome will determine the tunnel length of our phaco incision. If the angle is very flat and the blade is right against the ocular surface, the tunnel length will be long. If the angle is greater and the blade is now more parallel to the iris plane, the tunnel length will be shorter. We can vary this angle as we make the incision to tailor the technique to the anatomy so that every eye has a great incision.

This angle tends to be about 30 degrees (Figure 4) but it can vary based on the patient's anatomy. The corneal curvature plays a role as does the corneal thickness. There are variations in human anatomy so the surgeon must be able to make adjustments to provide the ideal result for each individual eye. If your incisions tend to be too short, then using a smaller angle with the tip of the keratome angled more toward the corneal apex is appropriate. If your incisions tend to be too long, then using a larger angle will allow the tip of the keratome to enter the anterior chamber sooner, resulting in a shorter tunnel length.

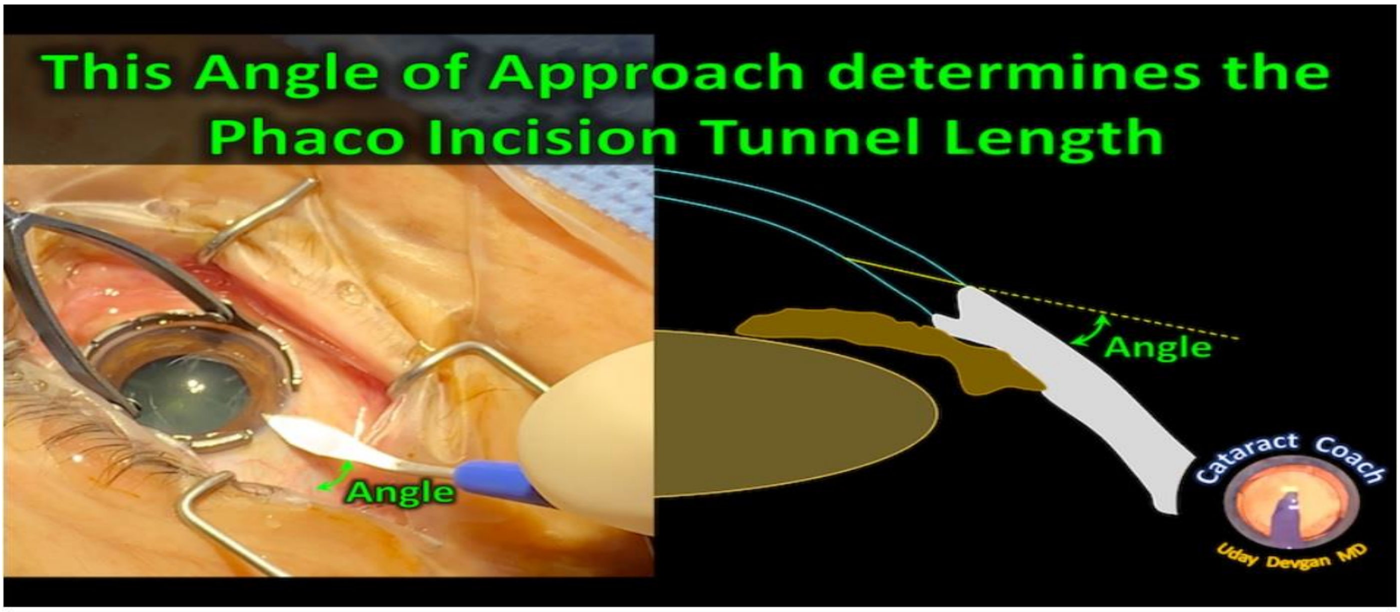


Figure 4: The ideal angle of approach for most incisions is about 30 degrees but it can vary depending on the anatomy and the surgeon's preferences.

Center the IOL, particularly if there is an optic with diffractive rings, and dial in the correct toric axis

With new technology IOLs, we have the ability to address corneal astigmatism as well as provide a wide range of vision without glasses. The toric correction on the IOL must be aligned with the steep corneal axis and the diffractive rings of the multi-focal, trifocal, or extended-depth-of-field optic must be centered appropriately.

The technique that I prefer is to first align the toric marks of the IOL with the steep axis of the cornea and then center the diffractive rings using the Purkinje images (Figure 5). This ensures the best visual outcomes for the patient.

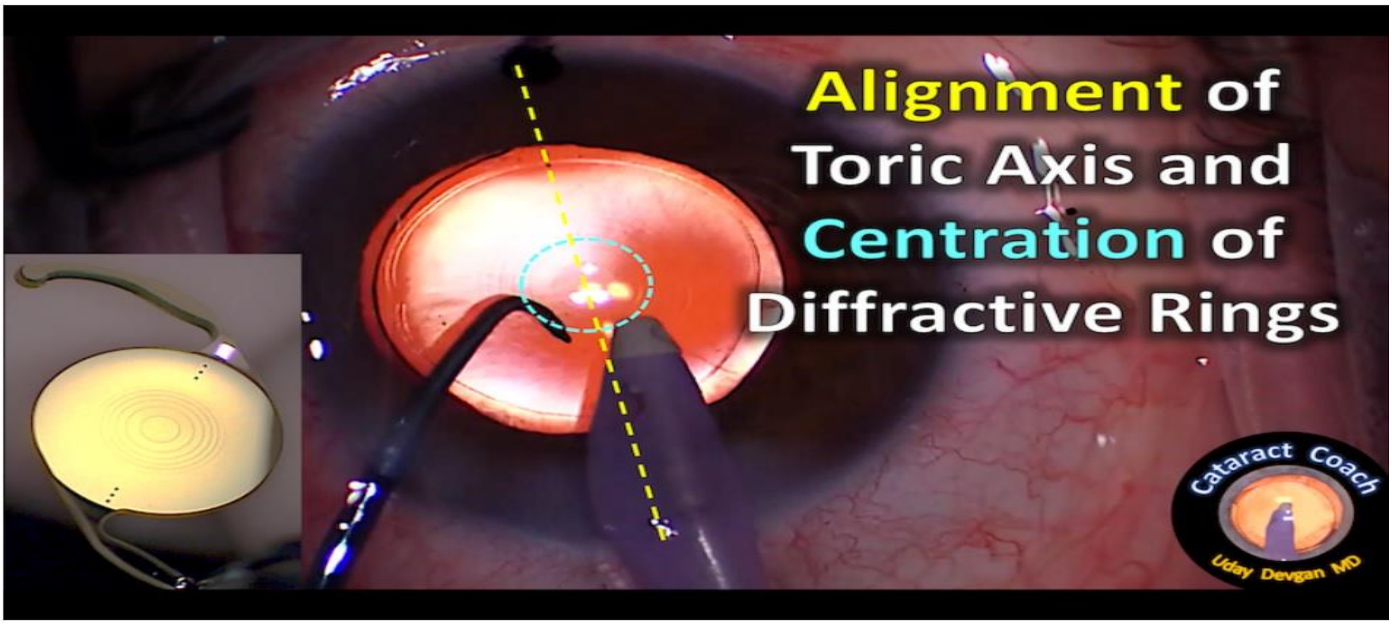


Figure 5: The IOL must be properly aligned with the astigmatic axis and also centered with respect to the diffractive rings in order to give the best visual results.

We enjoy performing cataract surgery as much as our patients enjoy the visual results, and we take pride in every case that we do. **Think of the phaco incision, capsulorhexis, and IOL centration as your "signature" on every cataract surgery that you perform.** These are the three most obvious signs of prior cataract surgery and they are a reflection of the surgeon's meticulous attention to detail. We want to strive to make a beautiful incision with balanced architecture and a round and appropriately sized capsulorhexis. Then, the well-centered IOL will perform at its best and produce the best vision for our patients.

25. Title: **Divide and Conquer Phaco Technique**

To facilitate the removal of the cataract nucleus with the phaco probe, it is helpful to divide it into quadrants or segments, which are more easily extracted. The original method of "one-handed" phaco used ultrasound energy to "bowl out" the nucleus; however, this required a lot of energy and was rather slow and cumbersome. While there are still some surgeons who continue to perform one-handed phaco, using a method to mechanically disassemble the nucleus allows easier removal.

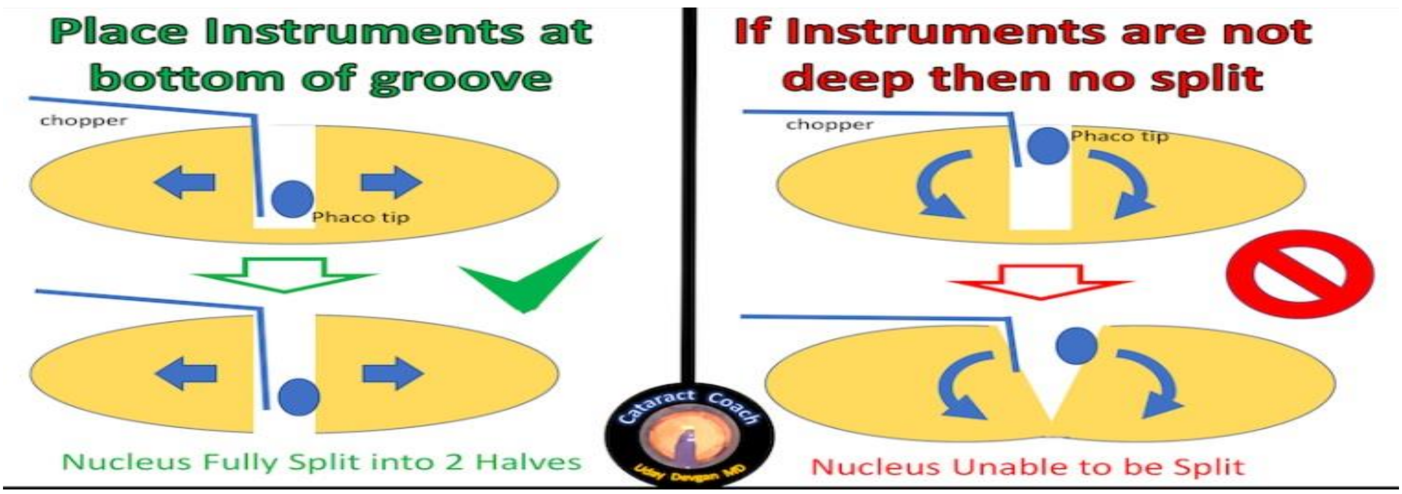
The phaco chop technique is one of the most effective, efficient, and safe nucleo-fractis techniques, but it has a learning curve that is not easy for beginning surgeons. For this reason, most of my ophthalmology residents start out by learning the divide-and-conquer technique which many credits to **Howard Gimbel MD, and his 1991 publication**. Please do understand that I rarely perform Divide-and-Conquer because it is inferior to Phaco Chop, but it is a reasonable first step in learning modern-day cataract surgery for novice surgeons.

In the divide-and-conquer technique, the phaco probe is first used to sculpt grooves into the nucleus, and then a second instrument is used to crack the nucleus into pieces, which can then be easily removed. For creating the groove, the phaco settings should be optimized for sculpting. Use a high pulse rate of 60 to 120 pulses per second, a duty cycle of 50% or more, and a maximum power setting of 20% to 60%, depending on the density of the nucleus. If your phaco machine does not have the ability to do a high pulse rate and a variable duty cycle, then it is acceptable to use continuous phaco energy. Be aware that the continuous phaco energy mode will put more energy into the eye and may lead to a high rate of corneal endothelial cell loss. For fluidics, the goal is to simply keep the anterior chamber deep and well-formed while providing a small amount of flow and vacuum to aspirate the sculpted cataract material.

- **Sculpting the grooves**

Start the grooves as close to the subincisional area as possible so that they have the longest length possible. Be careful not to hit the edge of the capsulorhexis with the phaco probe, and continue to sculpt the grooves deeper into the lens material. With an average nucleus, there is a depth of about **4 mm** centrally and less peripherally. You should have grooves that are at least half the depth of the nucleus in order to facilitate cracking. A softer nucleus may require a deeper groove compared to a denser nucleus in which propagation of the crack is facilitated.

Use the phaco probe and the second instrument to rotate the nucleus 90° and make a new groove. Once completed, the two intersecting grooves will form a **plus sign** and will segment the nucleus into four quadrants. To crack the nucleus into quadrants, a second instrument is placed into the groove along with the phaco probe tip. If the instruments are placed too shallow, the crack will be incomplete and the pieces will not separate. The proper method is to place the instruments deep within the grooves, then pull them apart. This will result in a complete crack with the separation of the nucleus into distinct pieces.



❖ **Change phaco settings**

Once the nucleus is fully cracked and separated into four quadrants, the phaco settings should be changed. The phaco power settings can be changed to a lower pulse rate, between 10 and 30 pulses per second, a somewhat lower duty cycle of 30% to 50%, and a lower maximum power setting of about half of what was used for grooving. For fluidics, it is important to have more holding power, which means more vacuum. Depending on the phaco needle size, the vacuum level should be 300 mm Hg to 500 mm Hg, and the flow rate should be 30 cc/min to 50 cc/min. Make sure to raise the bottle height to ensure that the inflow of fluid into the anterior chamber exceeds the outflow of fluid in order to keep things stable. **Use the phaco probe's vacuum to bring the pieces out of the capsular bag and to the iris plane. This is the ideal location, as it is far enough from the corneal endothelium and the capsular bag.** Continue to bring the quadrants to the iris plane and phaco-aspirate them. This is the technique of divide-and-conquer for nucleus removal.

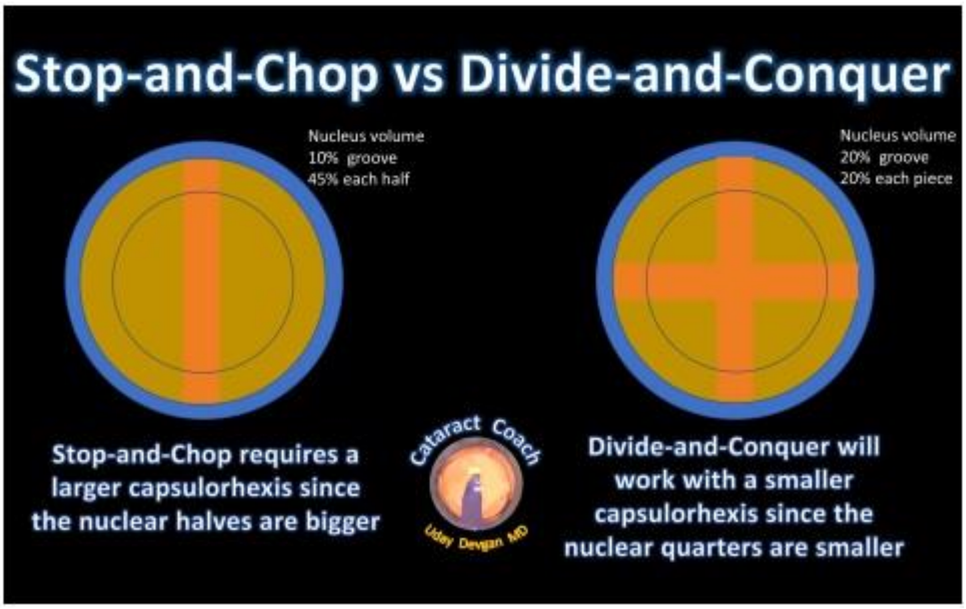
26. Title: **Stop-and-Chop Technique for Cataract Surgery**

The Stop-and-Chop technique for nucleus removal during cataract surgery blends aspects of the Divide-and-Conquer method with some Phaco Chop. Some surgeons use it as a stepping stone before moving to full chop techniques. Others stick with doing stop-and-chop for their entire careers.

The surgeon behind Stop-and-Chop is Paul Koch MD from Rhode Island, USA who coined both the term and the technique in **1994**. The idea is to make a central groove in the nucleus and crack it into two hemi-sections, then instead of proceeding to more grooving as with the divide-and-conquer technique, you "stop and chop" the nuclear halves.

"The procedure begins as a routine nuclear cracking technique and then stops. It continues as a chop technique." — Paul Koch MD

For this technique, **it is critical that the capsulorhexis is of sufficient size, at least 5 mm in diameter**. For Divide-and-Conquer a smaller capsulorhexis can be used since each of the four quadrants is smaller than the two nuclear halves in Stop-and-Chop.



One key to remember is that the depth of the initial groove needs to be more in softer cataracts in order to propagate the complete cracking of the posterior plate. But the deeper the groove, the closer you are to the posterior capsule. I think that (Dr. Devgan) stop-and-chop is a better technique than divide-and-conquer, and it's a good stepping stone toward doing a completely phaco-chop technique.

In summary: **stop and chop is half divide and conquer and half chop**. sculpt a groove and crack the nucleus into two halves (like divide and conquer), but then chop each half into quadrants or smaller. Divide and conquer uses two grooves to crack the nucleus into four quadrants.

26. Title: **Review: Beginning Surgeon Learns Phaco Chop**

Over the past 20 years of teaching ophthalmology residents, I have learned that it takes a resident about 100 cataract surgeries to develop sufficient intra-ocular skills to progress to phaco chop. This varies and some residents are able to perform phaco chop earlier in the learning curve while others may defer advancing their skills until years later. But I am convinced that any ophthalmologist in training can learn phaco chop. And this also applies to surgeons already in practice, too.

For the first few phaco chop cases, choose a patient with sufficient nuclear density, somewhere in the 2+ to 3+ range. This allows the chop to propagate but it is not so dense as to become fibrous and difficult to separate. The phaco tip needs to show enough metal to bury the tip into the nucleus (until the silicone sleeve touches the nucleus).

For initial phaco parameters, try these as a starting point:

- Use a 19-gauge phaco needle, either bent or straight, 30 degrees
- set the vacuum level high enough to have holding power, at least 350 mmHg
- a good starting flow rate is 30 cc/min
- choose an infusion pressure (or bottle height) to give sufficient inflow (85 mmHg or 100 cm bottle height)
- phaco power should be sufficient to embed the tip (30 to 50% starting)
- use of phaco power modulations is up to surgeon preference

The phaco tip is embedded into the central nucleus, just inside the sub-incisional capsulorhexis. The chopper is then carefully placed around the lens equator (horizontal chop), within the central dense nucleus (vertical chop), or in the mid-periphery of the nucleus (combo chop). The phaco probe is then held relatively still while the phaco chopper begins to split the nucleus, then the phaco probe is used to help fully separate the pieces. You must make sure that the nucleus is being held with a high vacuum during this process.

The most critical key is that you only have a window of about 1 or 2 seconds in which to accomplish this chop. Once the vacuum level drops, the nucleus is no longer being fixated, and the chop is likely to fail.

27. Title: **Learning Vertical Chop**

Vertical chop means that both the phaco probe and the chopper are placed within the capsulorhexis and then both are embedded into the nucleus. By pulling the two instruments apart, a cleavage plane is created and then propagated through the entire nucleus, thereby splitting it in half. The advantage is that there is no need to place the chopper around the lens equator, but this does require a sufficient amount of nuclear sclerotic density in order to create separate heminuclear pieces.

https://www.youtube.com/watch?v=I706B6K3Ohw

28. Title: **Complete Toric IOL Case: from Marking to Alignment**

Toric IOLs allow us to surgically treat corneal astigmatism at the time of cataract surgery thereby providing our patients with better vision without spectacles. The key is to have a toric IOL that is matched to the eye and aligned in an appropriate manner.

In the pre-operative evaluation, **we need to determine the total corneal astigmatism prior to cataract surgery**. Corneal topography, tomography, and keratometry are all helpful and will hopefully be quite similar. Note that of these, only corneal tomography will allow direct measurement of the posterior corneal surface. When the degree of total corneal astigmatism is determined, **we must also find the steep and flat axes**. **We also want corneal astigmatism to be regular, symmetric, and stable**. The phaco incision that we create will also affect astigmatism, so we must factor that into the calculations. Remember that astigmatism is a vector which means it has both a magnitude and a direction. With our phaco incision, we will affect the magnitude but we can minimize any change in direction (or axis).

Imagine an airplane flying with a direct headwind or a perfectly aligned tailwind: the speed of the plane will either speed up (with a tailwind) or slow down (with a headwind), but the plane will not be blown away from its intended direction. If we have a crosswind that hits the plane at an angle then both the speed and direction of the plane will change. This also applies to astigmatism: **if our phaco incision is on the steep axis or the flat axis then total astigmatism will either increase (if the incision is on the flat axis) or decrease (if the incision is on the steep axis), but the direction (axis) of astigmatism will not change**. This is why I make my phaco incision on the steep axis in this surgery. **The four black dots at the limbus are intended to mark the cardinal meridians (0°, 90°, 180°, and 270°)** and then the Mendez degree gauge is used to find the best fit for these marks. It is very close but not perfectly exact, which is acceptable because these toric IOLs come in half-diopter steps for both spherical and toric power.

The patient in this case started with:

- K: 43.00 x 108 / 45.00 x 018 (average K = 44.00, 2 D of corneal astigmatism)
- MRx: +0.50 +1.75 x 020 gives 20/60 vision (20/100 uncorrected vision)

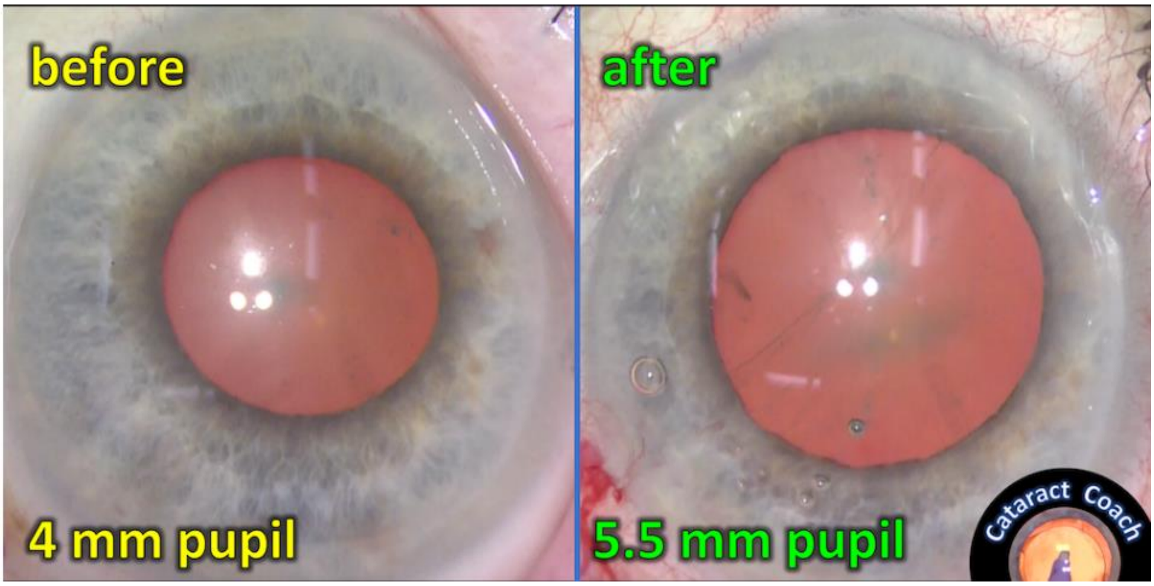
After surgery, the results are:

- K: 43.25 x 108 / 44.75 x 018 (average K = 44.00, 1.5 D of corneal astigmatism)
- MRx: -0.25 +0.25 x 020 gives 20/20 vision (20/20 uncorrected vision)

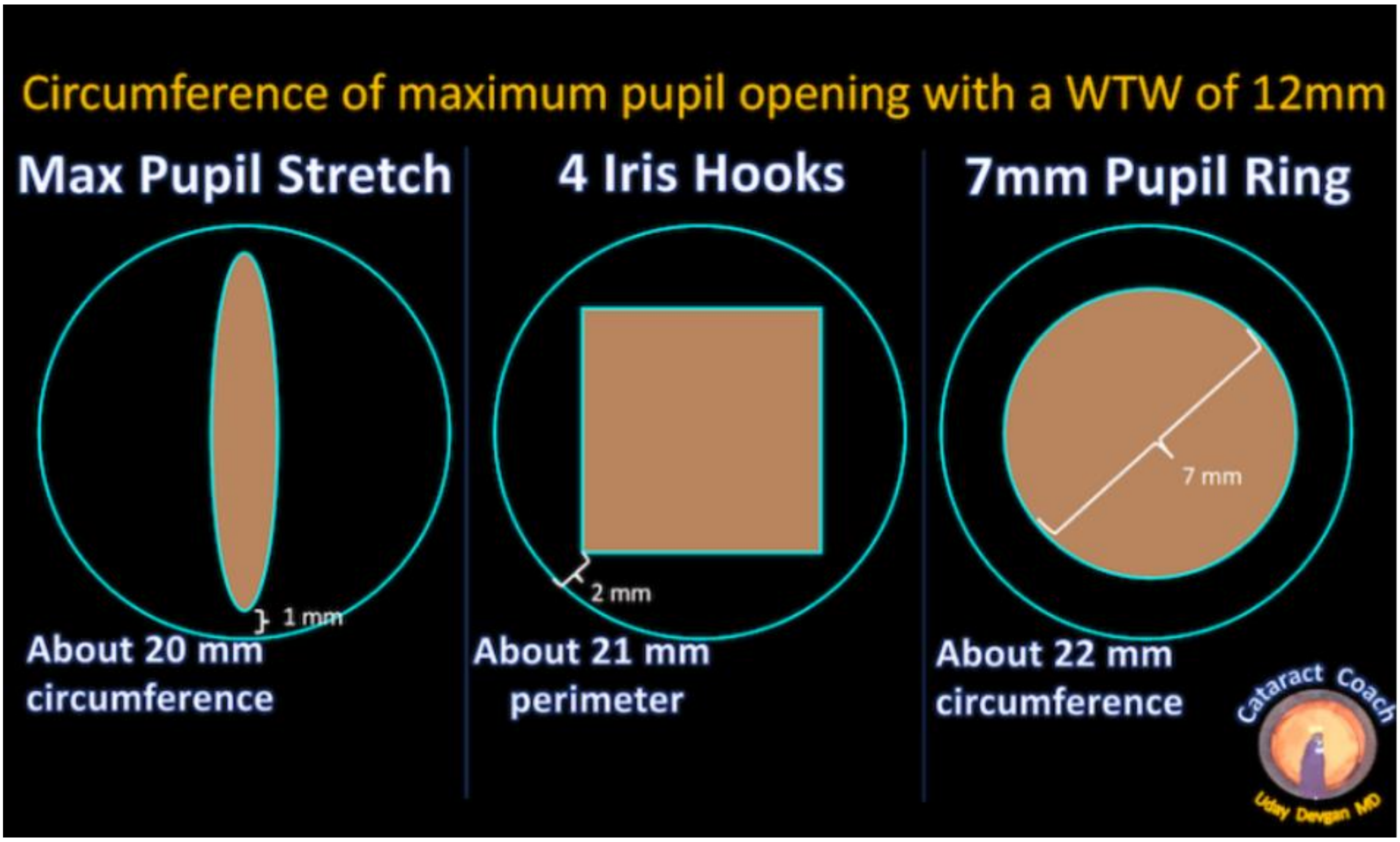
https://www.youtube.com/watch?v=dAzb-wU7mgU

29. Title: Learn the Pupil Stretch Technique

Stretching the pupil during cataract surgery is a safe and effective way to improve access via mechanical dilation. While there are special instruments available to perform this technique, I have found that simply using two choppers or similar instruments (Y-hook, Push-Pull, etc) is easy and effective. The pupil is stretching towards the angle of the eye and this will cause micro-tears in the sphincter and pupil margin. Next, visco-mydriasis using the viscoelastic is effective to hold the pupil open during capsulorhexis creation. In this case, we started with a 4 mm pupil and ended with a 5.5 mm pupil.



How does it compare to using other methods of pupil expansion? It turns out that all of these methods (stretching, iris hooks, pupil rings) cause about the same degree of total stretching and the circumference of the expansion is about the same.



30. Title: **Resident Double Capsulorhexis for White Cataract**

We know that intumescent white cataracts have a pressurized capsular bag with the milky white, liquefied cortex material. And we have shown many different techniques for safely dealing with this, **with my favorite being the double capsulorhexis technique**.

This video shows a senior resident successfully performing this double capsulorhexis technique, including using micro-scissors to start the second capsulorhexis. There is great learning here for young ophthalmologists and a great review for seasoned surgeons.

https://www.youtube.com/watch?v=bK0nv3dfc28

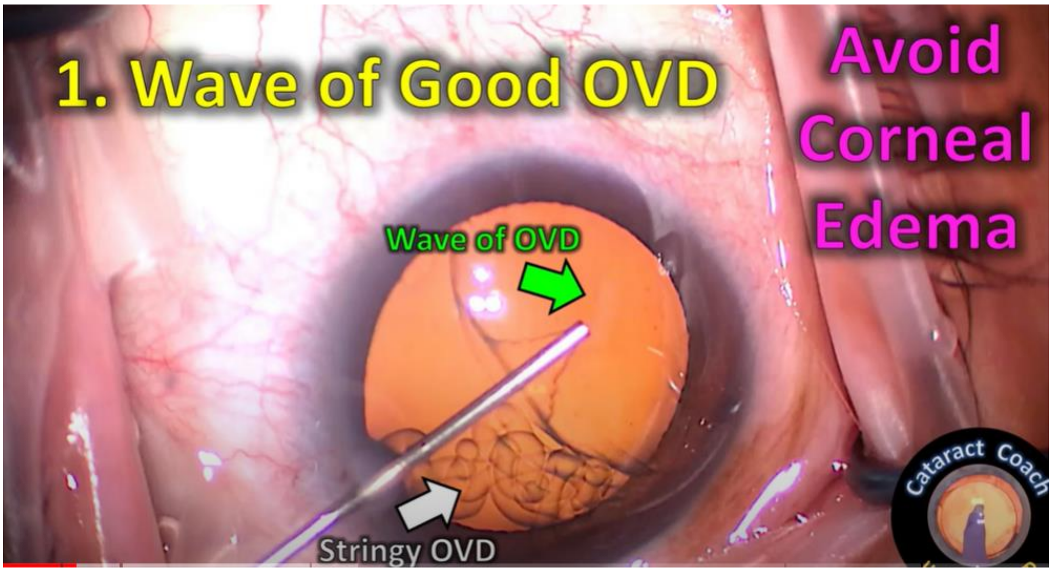
31. Title: **Secrets to Avoid Corneal Edema after Cataract Surgery**

Corneal edema can occur after cataract surgery due to a number of factors such as a **higher degree of ultrasonic energy or more fluid being used during surgery**. Also, **operating closer to the corneal endothelium and difficulty with pivoting within incisions will influence the degree of corneal compromise after surgery.** Fortunately, in almost all cases the corneal edema resolves with time and the patient achieves a good visual outcome.

Having a clear cornea on post-op day one makes for incredibly happy patients. And the surgeon is quite happy, too. There are steps you can take to achieve this goal. These "secrets" are well-known to advanced and highly talented surgeons but are often a mystery to the newer and less-experienced ophthalmologists.

1. **Wave of Good OVD**:

The **wave** of OVD coats the corneal endothelium. If its becomes stringy OVD; it won't protect the endothelium very well.



2. **Make a Great Incision**

Well-sealed with great architecture incision helps in avoiding edema postoperatively

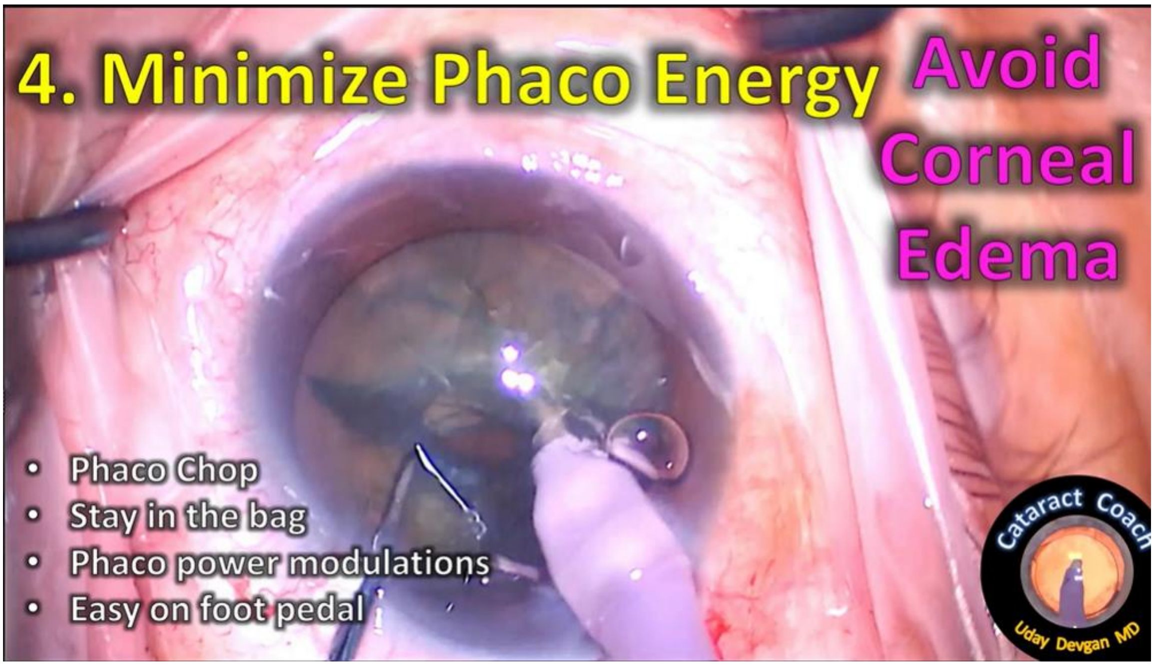
3. **Try to be efficient**

Avoid additional steps that prolong the surgery time. E.g., you need only forceps to do perfect capsulorhexis without the need for a cystotome. Prolonging the time of surgery increase the risk of inflammation and thus corneal edema develops.

4. **Recoat Endothelium with OVD after Hydro-Dissection**

Because hydro-dissection causes loss of OVD.

5. **Minimize Phaco Energy**



Avoid the divide and conquer technique; it needs more energy and; thus, more corneal edema. Instead, use the phaco chop technique and stay in the capsular bag with phaco power modulations. Use ultrasonic energy as least as possible. Minimize the amount of fluid as well.

Remember what's the volume of AC? A quarter of one CC. If you add the capsular bag and the posterior capsule: maybe another quarter of one CC. That's a half-CC. if you go over one bottle of BSS (500 cc). think of that, 500 cc means you turn it over 1000 times!

6. **Operate at the Level of Iris Plane**

Be away from operating near the corneal endothelium. Operate at the level of the iris plane or even deeper.

7. **Remove All OVD from the Eye**

Remove all OVD from the eye including from behind the IOL as well as the angle of the eye "angle sweep" method. If you leave viscoelastic in the eye; it will block the TM and very high spikes in IOP. Very high IOP will result in corneal edema

8. **Use Only Mild Hydration to Seal the Incision**

Avoid inducing huge white spots against the lateral walls of the incision. Those have a lot of temporary astigmatism and even can spread to the center of the cornea resulting in central corneal edema.

Someone asked: Would leaving a large air bubble in the anterior chamber help against developing post-op corneal edema? Dr. Uday replied: **The air bubble will make little difference. I do not recommend it**.

32. Title: **Unusual Tough Cases**

Here you can find plenty of them: https://cataractcoach.com/category/unusual-cases/

33. Title: **Advice for young ophthalmologists for future success**

https://www.youtube.com/watch?v=CztPCggNaUA

Luck is not just a chance, luck is created

The harder you work, the lucky you get

It's the horse, not the track, to win the race

Compete with yourself, not with others