Phaco Chop: Pearls and Pitfalls

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Introduction

Since Kunihiro Nagahara's original presentation at the 1993 ASCRS meeting, several different variations of chopping have evolved. Conceptually these can be divided into two main categories. I call the classic Nagahara technique **horizontal** chopping, because the instrument tips move toward each other in the horizontal plane during the chop. In **vertical** chopping, the two instrument tips move towards each other in the vertical plane in order to create the fracture. Although David Dillman later popularized the name "Phaco Quick Chop", Hideharu Fukasaku's "Phaco Snap and Split" was the first incarnation of this concept.

All chopping techniques utilize manual instrument forces to segment the nucleus, thereby replacing the ultrasound power otherwise needed to sculpt grooves. Such energy efficiency is possible because the lamellar orientation of the lens fibers creates natural fracture planes within the hardened nucleus that are exploited by the chopping maneuver.

These smaller nuclear segments are then elevated into the supracapsular space for phaco-assisted aspiration at a safe distance from the posterior capsule. I believe that phaco chop provides the same advantages as supracapsular phaco flip – namely efficiency, safety, and reduced stress on the capsular bag – without the difficulty of prolapsing the entire nucleus out of the bag in one piece.

WHY LEARN PHACO CHOP?

Modern phaco strategies seek to subdivide the nucleus into smaller maneuverable pieces. This "disassembly" of the nucleus achieves two advantages: (1) A 10-mm wide nucleus can be removed through an intact 5-mm capsulorrhexis. (2) The bulk of the nuclear material is emulsified near the central pupil plane - at a safe distance from the posterior capsule and endothelium.

Hydrodissection separates the nucleus from the capsule and cortex so that it can spin within the capsular bag, but nucleus disassembly begins with hydrodelineation. Hydrodelineation cleaves apart a thin epinucleus, leaving a remaining core of firm endonucleus. The larger the core endonucleus, the smaller the epinucleus will be. It is the endonucleus that we are chopping.

Cracking vs. Phaco Chop

Most phaco surgeons then employ one of two basic strategies in order to fragment and subdivide the core nucleus. **Cracking** (as in "4 quadrant divide & conquer") requires cutting a deep groove across the diameter of the nucleus. In brunescent nuclei, the groove must extend down almost to the posterior capsule. As with a log that has been sawed through to 90% depth, the nucleus can then be cracked into two pieces. Each heminucleus can similarly be cracked in half.

Dr. Kunihiro Nagahara of Japan first introduced the concept of phaco chop. While the nucleus is impaled and immobilized with the phaco tip, a “chopper” instrument hooks the equator of the nucleus, and chops toward the phaco tip. The human lens fibers are arranged in lamellae oriented much like the grain of a piece of wood. He observed that because the chopping force is oriented parallel to these lamellae (“with the grain”) a natural cleavage plane is created. The nucleus is split into two pieces with surprisingly little force. In similar fashion, each heminucleus is chopped into 2-4 smaller pieces.

“Stop and Chop"

Dr. Paul Koch recognized that although the nucleus could be sliced into many parts, these pieces still fit tightly together within the capsular bag, like pieces in a jigsaw puzzle. The immobility of these pieces within the bag made it difficult to aspirate them out. The process of making a groove for the cracking technique creates working space within the capsular bag.

To create this desirable working space, Dr. Koch’s stop and chop technique begins with a central groove, which is used to crack the nucleus in half. One then stops cracking and chops the remaining sections. The initial grooved cavity provides space enough for the chopped pieces to be elevated out with the phaco tip.

“Non-stop” Phaco Chop:

I coined the term “non-stop” chop to describe chopping techniques that eliminate all sculpting. There are two main variations of “non-stop” chopping. I call the classic Nagahara-style **horizontal** chopping, because the instrument tips move toward each other in the horizontal plane. Dr. Hideharu Fukasaku introduced “Phaco Snap and Split” at the 1995 ASCRS. Dr. Vladimir Pfeifer’s “Phaco Crack” variation of chopping was introduced at the 1996 ASCRS and is a similar technique. This variation has been renamed “Phaco Quick Chop” by Dr. David Dillman. I call these variations **vertical** chopping because the instruments move toward each other in the vertical plane.

HORIZONTAL PHACO CHOP

The first step is to divide the nucleus in half without any sculpting. The chopping instrument passes peripherally beneath the anterior capsule, and hooks the equator of the nucleus. The central core of the nucleus is impaled proximally with the phaco tip and held with position 2. The chopping instrument is pulled toward the phaco tip, and upon contact, the two tips are moved slightly apart. The initial chop cuts through the nucleus distal to the phaco tip. The separating motion continues the fracture along a natural cleavage plane through the proximal remainder of the nucleus.

The nucleus is rotated 30-45 degrees clockwise, and the central core of the opposite heminucleus is impaled with the phaco tip. The bevel of the phaco tip is aligned parallel to and facing the surface it is about to impale. A small pie-shaped wedge is now created by the second chop. This first piece is the most difficult to remove. The strong holding force afforded by high vacuum will usually allow elevation of this first piece out of the bag. Alternatively, the curved tip of the microfinger can slip behind the equator of this nuclear piece in order to manually tumble it forward into the anterior chamber. The nucleus is rotated further, and the next piece is chopped and removed.

Many different horizontal chopping instruments have been designed. Our preferences are listed in the appendix. Horizontal choppers usually feature an elongated, but blunt-ended tip. The length is necessary to bisect thicker brunescent nuclei, and the inner cutting surface of the shaft may be sharpened for this purpose.

Rationale of Phaco Chop:

To create the groove for cracking, the nucleus must be "sawed" from anterior to posterior. As pointed out by Nagahara, this cutting motion is directed perpendicular to the lens lamellae ("against the grain"). Like sawing through a log lying on its side, multiple passes - back and forth - are required. Phaco chop would be analogous to placing the log upright on one end, and chopping it with an axe. One strike, parallel to the grain, splits the log in half.

In addition to requiring less phaco power and time, chopping minimizes the stress placed on the zonules. In order for a phaco stroke to cut through the nucleus, the lens must be immobilized. Like a vise holding a piece of wood, it is the zonules and capsule that grip and fixate the nucleus as the groove is cut by the phaco tip. With phaco chop, however, it is the phaco tip that braces the nucleus against the force of the chopper. This manual energy, generated by one instrument pushing against the other, replaces the need for ultrasound energy to subdivide the nucleus. All forces are directed centrally inward, and away from the zonules, rather than outward toward the zonules and capsule. This significant difference in zonular stress is readily appreciated when chopping and sculpting are compared from the Miyake-Apple viewpoint in cadaver eyes.

Phaco Chop for Complicated Cases:

These principles of decreased zonular stress and decreased phaco power define the indications for phaco chop. While advantageous for routine cases, the greatest value of phaco chop is in handling complicated phaco cases - those that entail greater risk of posterior capsule rupture or corneal decompensation.

1) Small pupils:

Small pupils complicate phaco for two reasons. First, working space within the pupillary plane is limited, which makes it harder to avoid aspirating or phacoing the iris. Non-stop phaco chop eliminates the necessity of using phaco behind the iris because the phaco tip rarely moves peripheral to the central 3 mm of the pupil. This decreases the chance of lacerating the capsulorhexis or pupillary margin with the phaco tip in these eyes.

Second, visualization of the lens is impaired. The iris hides the lens periphery, and the intensity of the red reflex is significantly reduced with each millimeter less of pupil diameter. A poor red reflex makes it difficult to judge the depth at which the phaco tip is cutting. This is a problem for cracking techniques where an adequately deep central trough is essential. Phaco chop is a more kinesthetic technique in which visualization of the phaco tip depth is not important. It is only important to visualize that the chopper is passing beneath the anterior capsule is it hooks the equator of the nucleus.

2) Mature cataracts:

Mature white (cortical) and brown (nuclear) cataracts are challenging for many reasons. The capsulorhexis is difficult to visualize because of the lack any red reflex and the liberation of cortical "milk" following the initial puncture. The excessive hydration of these lenses promotes peripheral radial extension of the developing capsule tear. The lack of a red reflex also makes nuclear removal more formidable. Without good visualization, the phaco tip or second instrument might inadvertently tear an intact capsulorhexis. Trypan blue staining has solved the problem of anterior capsular visualization – both as the capsulorhexis is created and during nuclear chopping and emulsification.

A poor or missing red reflex makes it difficult to judge the depth at which the phaco tip is cutting. This is a problem for cracking techniques where sculpting an adequately deep central trough is essential and where the appearance of an increasingly brighter red reflex is used to gauge the proximity of the posterior capsule. Unlike sculpting, phaco chop is a more kinesthetic technique in which visualization of the phaco tip depth is not important. Proper positioning of the chopper and phaco tips relies more on tactile rather than visual clues.

The more brunescent and sizable a mature nucleus is, the greater the risk of complications. By necessitating increased phaco power and time, the potential for wound burn and endothelial cell loss is increased. In addition, the excessive bulk, density, and size of these nuclei more directly transmits all of the instrumentation forces directly to the capsular bag. The increased capsular and zonular stress induced by maneuvers such as rotation, sculpting, and cracking makes posterior capsule rupture much more likely. The ability of phaco chop to reduce the amount of nuclear sculpting, the total phaco time and energy, and the stress on the zonules is a particular advantage in these high-risk eyes.

3) Loose zonules:

Cataracts with loose zonules are among the most challenging to remove. Predisposing factors include exfoliation, advanced age, trauma, retinopathy of prematurity, and prior intraocular surgery (e.g. some post-vitrectomy or trabeculectomy patients). Loose zonules pose three sets of problems for the phaco surgeon. First, the nucleus, epinucleus, and cortex do not easily separate from a capsule that is not firmly anchored. Thus, it may be hard to rotate the nucleus. Later on, aspirating epinucleus and cortex may pull the anterior capsule centrally together with the lens material.

Secondly, the zonules are more fragile. Aspirating the anterior capsule or adherent lens material may dehisce the zonules in that region. Pushing the nucleus against the capsular bag (as with sculpting), or forceful nuclear rotation may shear zonules 180 degrees away. Finally, less centrifugal tension by the zonules allows the flaccid central posterior capsule to trampoline forward. The phaco or I-A instruments may aspirate folds of redundant posterior capsule.

Phaco chop greatly reduces the stress placed on the zonules and capsule by replacing sculpting and cracking forces with the manual forces of one instrument pushing against another. Unlike with cracking, these manual forces are directed centripetally inward, rather than outward toward the zonules.

4) Problems with capsulorhexis or hydrodissection:

Everyone, regardless of experience can encounter problems with these steps. Failure to properly complete these preliminary maneuvers greatly complicates the ensuing phaco step. An inadvertent radial tear during capsulorhexis may result because of poor technique, chamber shallowing, loose zonules, poor visualization, or patient movement. A radial tear may also be created by phacoing the capsulotomy edge. A capsulorhexis is more difficult to achieve with poor visualization of the red reflex (e.g. mature nuclei, anterior cortical spokes, hazy cornea), shallow anterior chambers (e.g. very narrow angles), increased capsule elasticity (e.g. pediatric cataracts) or psuedo-elasticity (e.g. loose zonules).

A capsulorhexis renders the capsular bag very resistant to tearing. Like an elastic waistband, a capsulorrhexis stretches with forces such as cracking, without tearing. A single radial tear is precarious because all of the stress placed upon the capsule is transmitted to that single weak point. Enough stress will cause an anterior radial tear to extend around the equator into the posterior capsule. Nuclear cracking stretches the capsulotomy and is particularly risky with a single radial tear. Non-stop phaco chop eliminates the need for this step, and is the technique of choice when a radial tear has developed.

Hydrodissection to enable rotation of the nucleus is a prerequisite for safe cracking techniques. However, it may not be possible to rotate a very soft nucleus, or a nucleus in a patient with loose zonules. Phaco chop can "slice" the initial wedges of nucleus for removal without the need for rotation. These pie-shaped wedges can then be tumbled out using the chopping instrument.

Conclusion:

Nuclear cracking and phaco chop are both excellent techniques for routine phaco cases. "Non-stop" phaco chop provides the additional benefits of: (1) less phaco time and energy (2) less stress on the zonules and capsule (3) allowing the phaco tip to remain in the central 3-mm of the pupil. (4) a kinesthetic technique with less reliance on visualization of the phaco tip's depth
Phaco chop is therefore of particular advantage in complicated cases that carry increased risk of posterior capsule rupture or corneal decompensation. This is the primary benefit of mastering this technique.

<u>PHACO CHOP - TECHNIQUE</u>

Horizontal chopping works by fracturing the nucleus along a natural cleavage plane defined by the orientation of the lens lamellae. It requires that the bulk of the endonucleus be sandwiched and compressed in between the two instruments - namely the chopper tip and the phaco tip. If positioned properly, the resulting compression force of instrument against instrument will result in the fracture taking place. The denser the nucleus, the more compression force is required.

As with all phaco methods, a given technique must be somewhat tailored according to the characteristics of the individual nucleus. Most surgeons mentally classify nuclei according to <u>firmness</u>.

At the slit lamp, nucleus color progressing from yellow to gold to brown correlates with increasing firmness.

It is equally important to visualize or classify the **size** of the nucleus. The greater the diameter of the endonucleus, the greater the anterior-posterior thickness of the nucleus. While soft nuclei are always smaller, brunescent nuclei may range from small to large. At the slit lamp, some cataracts have a golden or brunescent fetal nucleus, but the peripheral nucleus is light yellow. This correlates with a small diameter endonucleus, and a generous epinucleus. Alternatively, the brunescence may extend all the way forward to the anterior capsule in another cataract. This indicates a huge endonucleus with a large diameter, greater a-p thickness, and minimal epinucleus. The key to differentiating between these two types is to examine the color and opalescence of the nucleus between the anterior capsule and the front edge of the fetal nucleus.

In order to crack a larger endonucleus, the sculpted trough must extend more peripherally and much deeper. This becomes obvious to anyone with experience with the 4-quadrant divide & conquer (4Q D&C) method. Understanding and anticipation of nuclear size is equally critical to the success of phaco chop in larger nuclei. The chopper tip and phaco tip must penetrate deeper toward the posterior capsule, and the two instrument tips must initially be positioned further apart from each other if the bulk of the larger nucleus is to be compressed in between them. If the two instrument tips are not deep enough prior to the start of the chop, only the anterior portion of the endonucleus will be compressed. The front surface will be scored, but a fracture will not result.

COMMON PITFALLS IN LEARNING PHACO CHOP:

1) Not hooking the nucleus equator with the chopper. The chopper should pass below the capsulorhexis edge and into the epinuclear space. The novice is afraid that fully inserting the chopper tip under the anterior capsule and around the lens equator will overly distend and tear the capsulorhexis. This should not occur, as long as there is an epinucleus present. The maneuver is contraindicated in a giant, brunescent nucleus with no epinucleus for this reason. If the chopper tip never starts deep enough, it will simply deflect over the anterior nucleus rather than penetrate into it.

Pearl: Insert the chopper tip first. This optimizes visualization for the most intimidating step of the chop, and allows one to test whether the chopper tip is adequately deep. As you slightly pull with the chopper, the nucleus moves if the chopper tip has hooked the equator. This tap test also confirms that the chopper is inside the bag, rather than outside the bag and into the zonules.

2) Elevating the chopper tip as the chop is performed. If this occurs, the core of the endonucleus will not be compressed during the chop motion. The chopper tip will only scratch or score the anterior surface of the nucleus, rather than driving through the central core. This tendency comes from fear of puncturing the posterior capsule with a deeply positioned chopper tip.

Pearl: It is usually more than 4.5 mm from anterior to posterior capsule. Even allowing for removal of the anterior epinucleus, this is a long way for a 1.5mm to 2.0 mm-long chopper tip to be able to reach the posterior capsule. To convince yourself of this, pause the next time you have removed an endonucleus but while the epinucleus is still present. Insert your favorite chopper and see how far posteriorly it must travel before it can touch the posterior epinucleus. This will help you visualize with confidence how much room you truly have.

3) Chopper shaft presses down on limbus during the chop motion. Leaning on the limbal side port incision causes corneal striae, displaces the globe, and may increase "posterior pressure". Chopping is an advanced maneuver of the non-dominant hand. It presupposes dexterity and comfort in bimanual maneuvers that is best acquired in techniques such as (4Q D&C).

Pearl: Prior to performing the critical initial chop, take some "practice" chops by moving the chopper within the anterior chamber, just above the nucleus. This will verify proper position of the non-dominant hand and the side port incision so that optimal orientation of the chopping instrument can be achieved. Also, if you have never used a large chopper-like second instrument, start using one with your standard divide and conquer cases. This will help you adapt to handling such a second instrument in a more comfortable setting.

4) Chopper placed outside the anterior capsule into the zonular space. This is more likely to happen with poor visualization of the anterior capsule and with a deficient epinuclear space (e.g. small pupils and large brunescent nuclei). The chopping attempt will result in a local zonular dialysis and appearance of a peripheral area of clear red reflex.

Pearl: Position the chopper tip before using the phaco tip. Start by aspirating some of the anterior epinucleus. This improves visualization of the underlying endonucleus. At the center of the pupil, place the chopper tip directly on the anterior endonuclear surface. By maintaining this contact as the chopper tip moves peripherally, it will pass beneath the capsulorhexis rim prior to hooking the equator of the endonucleus. As long as the chopper tip maintains contact with the endonucleus, the anterior capsule cannot come in between. If uncertain, test the chopper position by gently moving the nucleus toward you. The anterior capsule shouldn't move.

5) Phaco tip is too superficial and central. With firm nuclei of increased diameter, the phaco tip must be deep and proximal in order to sandwich as much of the core nucleus between the two instrument tips as possible. Sculpting habits give rise to an incorrect tendency to advance the phaco tip centrally and superficially while in position 3. If so, the ensuing chop will only compress the anterior third of the endonucleus and will fail to fracture the nucleus.

Pearl: With large, firm nuclei, keep the phaco tip just within the proximal capsulorrhexis edge, and aim it toward the optic nerve. Avoid letting it drift toward the center of the pupil in such nuclei. With brunescent lenses, burst mode can facilitate deeper penetration while maintaining a tight seal around the tip.

6) Inability to remove the first piece. With firm, large nuclei, the pieces fit tightly within the bag like pieces in a wooden jigsaw puzzle. Insufficient holding force by the phaco tip results in the piece getting knocked back off before it is fully lifted out.

Pearl: The larger and firmer the nucleus is, the smaller the first piece should be. High vacuum and larger phaco tips increase holding force. Burst mode can enhance the phaco tip's purchase of a firm nuclear piece. As an alternative, the microfinger can be used to manually tumble the piece out.

Although the pie-shaped piece somersaults forward, it is pivoting upon its apex. This prevents the sharp apical tip of the fragment from getting close to the posterior capsule.

STRATEGIES FOR CONVERTING TO PHACO CHOP:

Learning any new phaco technique is simplified and facilitated by optimal case selection. Large pupils with softer and smaller endonuclei are important, along with avoidance of problem characteristics (e.g. exfoliation, long axial length, poor corneal clarity, deep-set eyes, uncooperative patients, etc.). A larger capsulorhexis and a well hydrodissected, rotating nucleus makes phaco chop easier. Vigorous hydrodelineation facilitates visualization of the endonucleus and placement of the chopper just around its equator. Since horizontal chopping seeks to divide the endonucleus, hydrodelineation is an important step for this procedure.

The most difficult steps of "non-stop" phaco chop are the initial ones - the first chop through the entire diameter of the nucleus, and the creation and removal of the first piece. Each subsequent step in the procedure becomes progressively easier. Therefore, it would be ideal if one could learn the steps in a reverse order - starting with the easiest maneuvers first.

My game plan for teaching residents is as follows:

- Step 1: Learn and master 4-quadrant divide and conquer technique. Cracking is easier to master than chopping. Sculpting a deep trough is, in essence, a lamellar by lamellar dissection of the nucleus. Experience with 4Q D&C therefore teaches us the dimensions and relative density of all varieties of nuclei. Furthermore, if a chopping attempt fails, one needs a backup technique upon which to rely.

- Step 2: Become familiar with the larger profile of the chopper by using this as a second instrument during 4Q D&C. When performing 4Q D&C, try using a microfinger or chopper to tumble one of the quadrants out. As mentioned earlier, this maneuver can be used to tumble chopped fragments out of the bag. It is also provides practice hooking the equator of the endonucleus with the chopper

- Step 3: When performing 4Q D&C, aspirate and elevate one quadrant into the pupillary plane. Instead of simply emulsifying it, chop it in half. With visualization of the entire piece and no anterior or posterior capsule to worry about, one can concentrate on the positioning of the chopper, and the "feel" of the chopper cutting through nuclei of different density. Use the second quadrant to similarly experiment with the orientation of the chopper tip as it chops.

- Step 4: After removing two quadrants, don't sculpt a groove into the remaining heminucleus. Instead, impale and aspirate the center of the heminucleus, and carry it to the center of the pupil. One can now proceed to chop it into thirds with full visualization of the equator, and without having to pass the chopper tip peripherally beneath the anterior capsule.

- Step 5: Learn and master "stop and chop". Sculpt an adequately deep and long groove in order to crack the nucleus in half. Then "stop" sculpting, rotate slightly, and chop the remaining halves. This requires learning to place the chopper peripherally underneath the anterior capsule and around the nucleus equator. This is still much easier than chopping the full endonuclear diameter for three reasons. First, one is chopping across a shorter distance (equivalent to the radius rather than the diameter). Second, proper position and depth of the phaco tip is virtually guaranteed. By placing the phaco tip into the trough and up against the side of the heminucleus, the nucleus is now sandwiched between the phaco tip and a properly placed chopper tip. Finally, the trough provides vacant space into which to slide out the first chopped fragment.

- Step 6: Sculpt a "half" trough and rotate 180 degrees. Rather than complete the sculpting of the trough, instead impale into the unsculpted area, and chop the remaining half.

- Step 7: One is now ready to do the full "non-stop" or "pure" Nagahara chop in which the entire nuclear diameter is chopped in half without any sculpting or groove. Softer and smaller endonuclei should be mastered before progressing to firmer and larger endonuclei. Luckily, if the initial chop is unsuccessful, one can simply start to sculpt a trough and convert to the "stop and chop" technique. Partial viscodissection with a dispersive OVD causes a persistent elevation of the nasal anterior capsule away from the endonucleus. This greatly facilitates passage of the chopper tip between these two structures and into the equatorial fornix of the capsular bag.

VERTICAL PHACO CHOP

This excellent variation on chopping was conceived by Dr. Vladimir Pfeifer and Dr. Hideharu Fukasaku, and renamed "phaco quick chop" by Dr. David Dillman. Whereas the microfinger or Nagahara style chopper moves from the periphery centrally toward the phaco tip, the vertical chopper is used like a spike from above to impale downward into the nucleus just anterior to the centrally positioned phaco tip. The most important step is to bury the phaco tip as deeply into the endonucleus as possible. If done correctly, one should actually be able to lift the impaled, unsculpted nucleus upward toward the cornea. Depressing the sharp spiked tip downward, while simultaneously lifting the nucleus slightly upward creates a shearing force that fractures the nucleus. Once the fracture begins to propagate, a slight sideways separation of the instrument tips extends the fracture deeper until the entire nucleus is cleaved in half.

Much like a chisel would be used with a block of ice or granite, the spike tip can be used to break the nucleus into multiple pieces of variable size. For this reason, I believe the name "phaco-spike" or "phaco-chisel" would have better conveyed the mechanics of this technique. Just like a fork and knife, the two instruments cut the nucleus into "bite-sized" pieces that are small enough to be efficiently eaten by the phaco tip. The sharp vertical chopper tip stays central to the capsulorhexis and does not need to pass underneath the equator and out to the equator. This is the only way, therefore, to chop a nucleus when there is little to no epinucleus present. Several different vertical choppers have been designed as well. Most employ a sharpened tip that can impale and penetrate the nucleus.

The same game plan proposed for learning "non-stop" Nagahara-style chopping can be used to learn "phaco quick chop". The principles for this stepwise learning progression are identical.

COMPARISON OF HORIZONTAL AND VERTICAL CHOPPING

I employ and am comfortable using either chopping technique. Although they work according to different principles, they both provide the same universal advantages:

- reducing phaco time and power by replacing ultrasound energy with manual energy to fragment the nucleus into pieces
- reducing stress on the zonules and capsule by using the phaco tip to immobilize the nucleus against the force of a centripetally directed instrument
- keeping the phaco tip in the central 2 - 3 mm of the pupil

Because they complement each other in terms of advantages and drawbacks, I believe it is worth learning both variations. A comparison of the two methods follows.

Difficulty: These are both advanced techniques with a greater learning curve than 4Q D&C. Learning one of these techniques will make it easier to learn the other. Because Nagahara style chopping can be learned on softer and smaller nuclei, I believe that it is easier to learn this method first.

Risks: Like all phaco techniques, both methods entail some risk of capsular or zonular rupture. Because Nagahara-style chopping requires peripheral placement of the microfinger or chopper, there is the risk of going anterior to the capsulorrhexis and causing a localized zonular dehiscence. The risk of vertical chopping is that a firm nucleus can be pushed so posteriorly that it ruptures the posterior capsule. This can occur if the firm nucleus is not fully impaled and supported from below by the phaco tip. The downward pushing force of the chopper must be borne by the phaco tip, and not the posterior capsule.

Indications for Horizontal Chopping:

1) soft and smaller nuclei

Vertical chopping relies on a shearing force to snap the nucleus in half. Like cracking, this is difficult with soft nuclei, which are not firm or brittle enough. This is why one can break a cracker in half, but not a piece of bread. The microfinger or Nagahara style chopper literally cuts through the soft nucleus, rather than chopping it, which makes horizontal chopping the method of choice for these cases.

2) extremely deep anterior chambers (e.g. high myopes, post-vitrectomy eyes)

The phaco tip does not need to be quite as deep with horizontal chopping as it does with vertical chopping. This is particularly true in the case of softer and medium density nuclei. With horizontal chopping, it is more important for the chopper tip to be as deep as possible. In these eyes where the nucleus descends more far posteriorly, it may be difficult to get the phaco tip deep enough to accomplish the initial vertical chop of phaco quick chop. The ergonomics of the microfinger or Nagahara-style chopper allow them to be placed deeply enough even in these eyes.

3) very small pupils

Firmer and larger nuclei require that the vertical chops be performed more peripherally. Because the sharp vertical chopper tip cannot pass through the anterior capsule or iris, a very small pupil or small capsulorhexis may therefore limit use of this maneuver. Unlike with phaco quick chop, horizontal Nagahara chopping does not require visualization of the chopper tip during the chop maneuver. Being more kinesthetic than visual, it may be performed blindly behind the iris, as long as initial placement of the chopper tip underneath the capsulorrhexis edge is confirmed.

Indications for Vertical Chopping:

1) difficulty visualizing the capsulorhexis edge (e.g. anterior cortical spokes, poor corneal visualization)

It is crucial that the microfinger or Nagahara-style chopper pass beneath the anterior capsule edge. It this can't be visually confirmed, it is safer to perform phaco quick chop in which the chopping instrument does not need to be placed peripherally into the fornix of the capsular bag.

2) brunescent nuclei

For brunescent nuclei, I find that vertical chopping works best. The denser the lens, the sharper the tip should be. The Chang chopper (Katena) is maximally sharpened to better penetrate the firmest nuclei. The most important step is to bury the phaco tip as deeply into the central nuclear core as possible. A beveled, micro phaco tip has a slim profile that is best suited for penetrating a dense lens. Retracting the infusion sleeve and employing burst mode are also helpful.

Compared to horizontal chopping, quick chop is more likely to divide the leathery posterior plate of a thick lens because the fracture propagates vertically from the anterior nuclear surface toward the back. With Nagahara-style chopping, the fracture propagates in the horizontal direction, from one equatorial side to the other, and may not extend deeply enough to bisect the posterior plate.
As with chiseling a block of ice, vertical chopping can be used to create very small fragments. This versatility is nice when dealing with a large and bulky dense nucleus where smaller pieces must be created for maximal emulsification efficiency.

3) little or no epinucleus

Since the microfinger or Nagahara-style chopper passes into and occupies the epinuclear space, the thinner the epinucleus, the more difficult this maneuver is. By avoiding the need for instrumentation in the peripheral fornices of the capsular bag, vertical chopping may be preferable for progressively larger and denser nuclei (see #2 above). Indeed, lack of a sufficient epinucleus is a contraindication to horizontal chopping.

Conclusion: By reducing phaco power and zonular stress, "non-stop" phaco chop provides enormous advantages for complicated and higher risk cases. This justifies its inclusion in our surgical armamentarium. Mastering the steps in reverse order and understanding the principles and common pitfalls facilitates the transition to phaco chop. Horizontal and vertical chopping are complementary variations offering different advantages but common benefits.

Optimizing Machine Parameters for Phaco Chop - Fluidics

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Ultrasound and fluidic machine settings should be customized according to each individual surgeon's equipment, phaco technique, and level of experience. Surgeons may also further adjust machine parameters according to the density of the nucleus. Simply copying someone else's settings without understanding the rationale is never ideal. For example, the higher flow and vacuum settings used by an experienced surgeon may be too aggressive for a novice. However, as phaco technology evolves, the expansive array of programming options can truly be intimidating. The next two chapters will review general concepts that should guide surgeons performing or transitioning to phaco chop using a peristaltic pump system.

Phacodynamics – The Four Objectives

What are the benefits of modifying and customizing phaco machine parameters? With the availability of high vacuum and advanced phaco power modulations, the advantages of such maneuver-specific specialization are significant. As with a point-and-shoot camera, the simplicity of using a fixed set of parameters for the entire case is appealing. However, just as professional photographers know how to optimize their equipment for special situations, so too can phaco surgeons do the same. As the requirements change during the course of the case, one should dynamically modify the pump fluidics, the phaco power, and the ultrasound mode. Thanks to dual linear systems and multiple, pre-programmed memory settings, surgeons can now use the foot pedal to seamlessly alter these parameters intraoperatively.

Every phaco technique invokes a sequence of different maneuvers, each with its own phacodynamic requirements. As a conceptual framework for understanding fluidic and ultrasound strategies, one should consider the following four separate objectives that sequentially change in priority during any phaco case:

1. **Sculpting efficiency**
2. **Impaling/Holding power**
3. **Followability**
4. **Chamber stability**

With the exception of sculpting, chopping and divide-and-conquer techniques share these same objectives. If possible, one should assign a separate phaco memory setting for each objective. This allows one to pre-program a package of fluidic and ultrasound parameters that are optimized for each specific goal.

Basic Fluidic Principles

The first major option for parameter adjustment is pump fluidics. Of the peristaltic pump's two aspiration variables, **flow rate** (measured in cc/min) dictates the pump speed and therefore the speed of the procedure. Higher flow rates better attract particles to an unoccluded phaco tip and cause vacuum to build more rapidly after the tip is occluded. However, if things are happening too quickly, one should decrease the flow rate.

Vacuum (measured in mmHg) builds within the aspiration line in between the occluded phaco tip and the pump. Therefore, with a peristaltic pump, the vacuum level cannot rise until the tip is occluded with tissue, and will not exceed a maximum programmed level called the vacuum limit. Clinically, vacuum determines the strength with which the phaco tip grips nuclear material. Higher vacuum increases the "holding power", and one should therefore consider increasing the vacuum if the pieces keep falling off of the phaco tip.

Objective 1: Fluidics for sculpting efficiency

This objective applies to divide-and-conquer and stop and chop, but not to pure chopping techniques. During the sculpting stroke, the tip does not occlude as long as it keeps moving and avoids becoming embedded in the nucleus. This prevents the vacuum level from rising. Aspiration flow improves visibility by keeping the tip path clear of debris. Eventually, the tip slows down and must submerge into the peripheral lens as it passes beneath the capsulorhexis edge. At this point, particularly with soft lenses, a sudden rise in vacuum can cause the peripheral nucleus and capsular bag to rush into the tip. For this reason, one should select a relatively low vacuum setting for sculpting. Since holding power is superfluous during sculpting, high vacuum adds unnecessary risk to this step.

Phaco chop objectives

With both horizontal and vertical phaco chop, there are three sequential steps used to remove the endonucleus. The first step is chopping the nucleus into progressively smaller fragments. Second, the phaco tip elevates and carries these fragments out of the capsular bag into the pupillary plane. Finally, these mobilized pieces are removed by "phaco-assisted" aspiration in the supracapsular location at a safe distance from the posterior capsule. For the first two maneuvers, the key fluidic attribute is **holding power**. For the last maneuver, **followability** and **chamber stability** are the primary objectives. As stated earlier, these three objectives assume different priorities during the course of the case.

Objective 2: Fluidics for holding power

For chopping, the phaco tip performs two distinct maneuvers that are facilitated by high vacuum. First, the tip impales the nucleus to immobilize it against the incoming chop. A strong purchase will prevent the chopper from dislodging or torquing the nucleus. This is particularly important for vertical chopping where a shearing motion is generated. Second, the tip must grip and separate one hemi-section from the other. While flow rate is less important for these steps, high vacuum increases surgeon control of the chopping and separating motions. Next, the chopped fragments are elevated out of the capsular bag, with the first interlocked pieces being the most difficult to extract. As it does for elevating quadrants in the divide-and-conquer technique, high vacuum maximizes holding power for this step.

Objective 3: Fluidics for followability

The third and final maneuver in phaco chop is scavenging and emulsifying the mobile chopped fragments. By increasing the force by which material is pulled through the tip, higher vacuum levels can decrease the amount of phaco energy needed to evacuate fragments. However, because the tip remains either unoccluded or partially occluded, flow rate is much more important here. A higher flow rate helps to attract loose fragments to the phaco tip, and allows the tip to re-engage a piece that momentarily deflects away. Ideally, pieces should gravitate toward a stationary, and centrally held phaco tip. If one has to chase pieces into the periphery, the flow rate may need to be increased.

Objective 4: Fluidics for chamber stability

As progressively more of the nucleus is removed, the posterior capsule becomes exposed to the phaco tip. As the final fragments are removed, any forward trampolining of the posterior capsule is dangerous, and chamber stability becomes crucial. This is especially true if the epinucleus is thin or absent. Since holding power is unnecessary at this stage, high vacuum becomes a liability and should be lowered to eliminate any chance of surge. This lower vacuum setting will also be appropriate for the epinucleus and for soft nuclei, where holding power is nonessential.

Post occlusion surge

As stated earlier, high vacuum provides two sets of advantages that benefit all techniques. First, it increases the strength with which a nuclear piece is held at the tip. Second, it increases the mechanical force with which material is sucked through the phaco needle. This can decrease the requirement for ultrasound energy.

The unwanted phenomenon of post occlusion surge limits how high the vacuum can be safely set. Following tip occlusion, vacuum quickly rises to the maximum pre-programmed limit. Surge occurs as this occlusion breaks and fluid from the anterior chamber rushes in through the tip to equilibrate the lower pressure environment of the aspiration line. A minor degree of surge produces a momentary flicker of iris movement. Severe surge may collapse the anterior chamber.

Post occlusion surge is probably the most common cause of posterior capsule rupture during nuclear emulsification. The amount of nucleus still present at the time of the surge affects the risk. A mild to moderate degree of surge is of little consequence with enough nucleus present to shield the tip. However, as progressively more nucleus is removed, the same amount of surge can cause the posterior capsule to abruptly vault into the unguarded phaco tip.

At the same machine settings, the phaco method and the nuclear density also affect the amount of surge seen. Because surge results from occlusion break at the maximum vacuum level, tip occlusion is required. This explains why surge may be absent with sculpting, but quite evident with chopping where the phaco tip impales the nucleus during every chop. At the same vacuum setting surge is often more evident with soft nuclei than with dense nuclei. As fragments are being evacuated, the softer lens material molds to and quickly plugs the phaco tip. Maximum vacuum levels are rapidly and repeatedly attained. In contrast, when brunescent fragments are emulsified, their rigid contours neither conform to nor completely plug the phaco tip. These partial occlusions generate surge less often because maximum vacuum levels are not reached.

Surge prevention strategies

Phaco machine manufacturers have devised numerous strategies for minimizing surge. The goal has always been to provide surgeons with the advantages of high vacuum, without the associated danger. One set of strategies addresses infusion. These range from a simple bottle height extender to forced infusion pumps available with combined anterior-posterior segment machines, such as the Accurus (Alcon) and Millennium (Bausch & Lomb). The Surgical Design machine utilizes a second auxiliary irrigation bottle. Alcon offers a higher flow irrigation sleeve as an option with the Infinity system.

With respect to outflow, so-called "smart" pump technologies have been an important innovation. The B & L Millennium was the first machine to offer dual linear foot pedal control over ultrasound and vacuum. This allows the surgeon to lower vacuum as the occlusion is about to break. The occlusion mode programming of the AMO Diplomax and Sovereign machines can automate a similar change in pump speed pre and post occlusion. AMO uses fluid venting to create an entirely closed, bubble-free aspiration system with their Sovereign & Signature machines. Using microprocessors to monitor vacuum at remarkably frequent intervals, a dedicated fluidic computer regulates the pump to minimize surge. Alcon and B&L offer similarly advanced fluidic improvements with the Infinity and Stellaris platforms.

Another approach addresses the aspiration tubing where reducing the system compliance diminishes surge. Virtually all companies have evolved toward stiff-walled, low compliance tubing with narrower lumens that resist collapse. This option may be called a "high vacuum" tubing or cassette.

A final set of surge reducing strategies involves phaco tip design. The overall resistance to outflow is determined by the narrowest caliber lumen in the aspiration system. This is usually the internal diameter of the phaco needle. Micro phaco needles (20-gauge instead of 19-gauge) reduce surge in this way. The flare tip designs produced by Alcon improve holding power by pairing a larger diameter tip opening with a narrower shaft. Momentary clogging with brunescent material is a potential problem with this design. Finally, the Alcon advanced bypass system (ABS) tip reduces surge by creating a shunt flow behind the occluded tip. This reduces air-venting resulting in lower compliance of the aspiration system.

Determining the vacuum limit – the "surge test".

After becoming familiar with the surge prevention features of their particular phaco system, surgeons should customize their individual parameters using the following "surge test". To facilitate tip occlusion, a soft-medium density nucleus should be used. One starts with a low flow rate and the "quadrant setting" – the vacuum limit used for quadrant emulsification in divide-and-conquer. With enough nucleus still present to shield the phaco tip from the posterior capsule, one holds an impaled nuclear fragment in the pupillary plane until the maximum vacuum setting is reached (identified by a beeping tone). Ultrasound is then applied and as the occlusion breaks, one gauges the amount of iris movement caused by the surge. To reduce surge, one can raise the bottle height, decrease the flow rate, or reduce the maximum vacuum setting.

If there is no surge, the vacuum setting is increased by 20-25%. By repeating this step, one will eventually detect an unacceptable amplitude of surge. At this point the maximum "safe" vacuum level has just been exceeded, and the vacuum limit must be lowered. Slight chamber bounce during the initial chopping maneuvers is tolerable as long as there is enough nucleus present to hold the posterior capsule back. However, as the last pieces of nucleus are removed and the posterior capsule is exposed, surge must be completely eliminated. The surge test teaches the surgeon what vacuum limits can be used for these steps.

Fluidics for removing epinucleus and cortex

For epinucleus and cortex, the main fluidic objective is the ability to aspirate lens material without ensnaring the capsule. Careful control of vacuum is key, and is best achieved by using linear control of vacuum in foot pedal position 2 for these steps. For epinucleus, this can be configured in a dedicated phaco memory setting. A reasonably high flow rate helps to attract material to the tip. However, the resulting rapid vacuum rise time reduces the surgeon's reaction time.

With linear control, one generally uses three different vacuum levels during cortical cleanup. When first trying to draw cortex to the tip without catching the capsule, ***low*** vacuum is safer. To loosen and strip the cortex, one needs increased vacuum to grasp the cortical "handle" without letting it go. However, excessive vacuum results in premature evacuation of the cortex. A ***medium*** level of vacuum that grips but doesn't consume the cortex is needed. Finally, a ***high*** vacuum level safely ingests the mobilized cortex once the aspirating port is facing the cornea and is positioned in the center of the pupil.

The same vacuum principles apply to aspirating the epinucleus with the phaco tip under linear control. When fishing for the epinucleus peripherally, the vacuum should be kept low (e.g. to 50 mmHg) to prevent aspirating the capsule. To draw the epinucleus centrally, one increases the vacuum hold (e.g. 125 mmHg) to avoid releasing it. Maximum vacuum (e.g. 200 mmHg) is used to flip or aspirate the shell once the phaco tip is in the safe, central zone. These sample vacuum settings apply to a 20-gauge phaco tip.

Surgical safety and efficiency are enhanced by appropriately balanced fluidics – parameters that are dynamically adjusted and matched to the different phacodynamic objectives during the case. In the next chapter, the interdependent relationship of fluidics with phaco power modulations is reviewed with respect to the same four phacodynamic objectives.

Optimizing Machine Parameters for Phaco Chop - Ultrasound

David F. Chang, M.D.

Ultrasound power

All machines provide surgeons with linear control of ultrasound power in foot pedal position 3. This allows the surgeon to vary the power according to the density of each nucleus and according to the requirements of each individual maneuver. Many surgeons misunderstand how the machine produces increasingly more power. As the pedal is depressed, it is not the frequency of vibration that changes, but rather the axial stroke length of the oscillating tip. 100% "power" means that the phaco tip is vibrating back and forth along the maximum longitudinal stroke length. 50% power means that the axial needle stroke is only half as long.

While learning to sculpt, every surgeon recognizes that the higher the power level is, the better the tip cuts through nuclear tissue. This is because progressively more cavitational energy is created. However, this creates a corresponding tendency to use excessive power while emulsifying mobile fragments. In contrast to sculpting, this maneuver requires aspiration to pull the piece toward the tip. However, the greater the stroke length of the phaco tip is, the greater the mechanical repelling force will be. Thus, if one is experiencing poor followability when emulsifying a dense fragment one should avoid the tendency to increase phaco power, which usually exacerbates the chatter. Instead, the counterintuitive response of decreasing power may improve followability by decreasing the repelling force of the tip. Like tuning a radio dial, the surgeon should use the foot pedal to find the most efficient power level (and therefore stroke length). Along the power continuum, this is the "sweet spot" between having too little power to cut and excessive power that repels.

In addition to increasing the repelling force, maximum power levels also generate greater frictional heat (due to longitudinal needle shaft vibration) and cavitational energy. Lowering the risk of incisional burn and endothelial cell loss are equally important goals of minimizing the ultrasound power level when possible.

Ultrasound power modulation

Power modulation refers to how and in what pattern ultrasound is delivered while in foot pedal position 3. Clinically, there are a variety of basic power modulations in common use – continuous mode, burst mode, pulse mode, and hyper-pulse mode. All produce different tissue effects that can either facilitate or impede the phaco objective desired. Non-longitudinal modes include torsional and transversal ultrasound.

Objective 1: Sculpting efficiency – Continuous mode

Continuous mode provides uninterrupted ultrasound and produces maximum cavitational energy. For these reasons continuous mode is typically used for sculpting. Cavitational waves emanate ahead of the vibrating tip and have the ability to disrupt material with minimal contact from the phaco tip. This is ideal for sculpting grooves where overly deep tip penetration risks contact with the underlying capsule. High power ultrasound can make the deepest lamellae of nucleus seemingly melt in front of the sculpting tip. However, this mode also delivers the most ultrasound energy into the eye. As described below, hyper-pulse, if available, can also be used for sculpting.

Objective 2: Impaling/Holding power – Burst mode

The powerful cavitational waves of continuous mode are a distinct disadvantage when trying to grip tissue with the phaco tip. With a toothpick, a single stab works best to impale a piece of melon. Further wiggling of the tip only serves to weaken the purchase. With brunescent nuclei, a continuously vibrating phaco tip tends to core out a small cavity around the tip, eroding the seal. A peristaltic pump cannot generate high vacuum if the tip does not stay embedded and occluded.

Burst mode is a power modality that was first introduced with the AMO Diplomax phaco machine. It is now available with most high-end phaco equipment platforms. Burst mode can be used to deliver a single momentary pulse of phaco energy. Bursts can be delivered individually or in rapid succession via foot pedal control. By embedding the tip without losing the surrounding tight seal, successive individual bursts of phaco are ideal for impaling and gripping dense nuclear material for chopping.

Burst mode typically delivers a fixed level of power that is pre-set on the machine console (panel control) rather than with the foot pedal. Since burst mode is advantageous for dense nuclei, higher powers are generally programmed. For this reason, burst mode may be dangerous for soft nuclear sections in the bag because it may penetrate too abruptly.

Objective 3: Followability - Pulse or hyper-pulse mode

The maximal cavitational force of continuous mode is also counterproductive for emulsifying mobile nuclear fragments. “Chatter” refers to the rattling, yo-yo like movement of nuclear pieces as they alternately contact and separate from the phaco tip. This results from the competing forces of suction (pump) and repulsion (longitudinal tip oscillation) acting upon nuclear material at the phaco tip. As explained earlier, excessive phaco power and stroke length actually kick nuclear particles away.

In pulse mode, each pulse of phaco (“on” time) is followed by an equally long pause (“off” time). Compared to continuous mode (always “on”) pulse mode interrupts the tip oscillation 50% of the time. Having these rest periods therefore reduces heat and energy delivery by cutting the net phaco time in half. In addition, the pump aspiration force competes with the tip repelling force only 50% of the time. Compared to continuous mode, pulse mode improves followability by favorably shifting the balance between these opposing forces at the tip.

Hyper-pulse mode

In 2001, AMO introduced a new power modulation for the Sovereign machine called WhiteStar technology. This author first coined the term “hyper-pulse” to convey the ability of dramatically increased pulse frequency to leverage the aforementioned advantages of pulse mode (DF. Chang, “Can cold phaco work for brunescent nuclei?” *Cataract & Refractive Surgery Today* 2001;1 :20-23). Alternatively called ultra-pulse, micro-pulse, or micro-burst, this software driven technology is now offered with other manufacturers’ platforms, such as those from Alcon and Bausch and Lomb.

Hyper-pulse represents a paradigm shift from traditional pulse mode in two ways. First, it can be programmed at rates ranging from 30 to 100 pulses per second (pps). This rapid interruption and fragmentation of phaco time helps to prevent heat buildup at the tip. Cadaver studies have demonstrated that even with the irrigation line clamped, the heat buildup remains below the clinical threshold for producing a wound burn. Most importantly, the phaco pulses utilize traditional ultrasound with the full continuum of power delivery. For this reason, there is no functional loss of cutting efficiency with brunescent tissue. This distinguishes hyper-pulse from other non-ultrasound “cold” modalities such as laser phaco, sonics, and pulsed fluid (Aqualase) that eliminate incisional heat but are relatively ineffective for dense nuclei.

The second major enhancement with hyper-pulse is the ability to alter the duty cycle, which refers to the percentage of time that ultrasound is active while in foot pedal position 3. Compared to the uninterrupted “on” time (ON-T) of continuous mode, pulse mode interrupts these “on” pulses with equally long rest periods of “off” time (OFF-T). Duty cycle expresses the percentage of time “on” and is equal to ON-T divided by (ON-T + OFF-T) [2]. The duty cycle is 100% for continuous mode and 50% for pulse mode, which means that pulse mode reduces ultrasound delivery by a factor of two. This is true whether one uses 3 pps or 6 pps.

In hyper-pulse mode, the duty cycle can be further varied by lengthening or shortening the rest periods. For example, following a 6 msec phaco pulse with a 12 msec rest period creates a 33% duty cycle and 55 pulses per second (pps). A 24 msec rest period would create a 20% duty cycle and 33 pps. These settings are a dramatic departure from traditional pulse mode (e.g. 4 pps = 125 msec pulse followed by a 125 msec rest = 50% duty cycle). The overall effect of hyper-pulse is to dramatically reduce heat and energy delivery without any loss of cutting efficiency. This is another way of saying that continuous mode phaco is an inefficient way of delivering far more energy than is necessary to accomplish the task.

Combining more frequent pulse interruptions with the lower duty cycle reduces the repelling force of the phaco tip as well. As a result, chatter that is particularly problematic with brunescent fragments is significantly diminished. This not only improves followability, but also lessens endothelial cell trauma caused by particle turbulence at the tip. Whereas burst mode is well suited for impaling dense nuclei for phaco chop, hyper-pulse with a low duty cycle is ideal for emulsifying mobile fragments.

Effective phaco time (EPT)

The ability to dynamically adjust phaco power and change power modulations creates tremendous variability in the net amount of ultrasound delivered during an individual case. Effective phaco time (EPT) attempts to quantify this by expressing what the equivalent phaco time would have been in continuous mode with 100% power. For example 2 minutes of continuous (100% duty cycle) phaco time using 25 % power would give a 30 second EPT [120 sec / 4]. Switching to pulse mode (50% duty cycle) would have further cut the EPT in half (15 seconds). Hyper-pulse with a 33% duty cycle would have cut the EPT by one third (10 seconds).

EPT is primarily affected by what percentage of maximum power level is used. Since there is no industry-wide standard for measuring stroke length, EPTs cannot be used to accurately compare machine performance from two different manufacturers. However, EPT is useful for comparisons within the same system. For instance, EPT will reflect the difference in ultrasound energy used for different grades of nucleus (brunescent versus soft), with different techniques (divide-and-conquer versus chop), and with different power modulations (hyper-pulse versus traditional pulse or continuous mode). EPT can also be used to compare the performance of new machines with predecessors from the same manufacturer (e.g. AMO Sovereign versus Diplomax, and Alcon Infinity versus Legacy).

Non-longitudinal Ultrasound

Introduced by Alcon in 2005, torsional phaco is a dramatically different mode of ultrasound. In contrast to its longitudinal axial movement with conventional ultrasound, the phaco tip moves from side to side in torsional mode. Nuclear tissue is disrupted with a shearing motion that significantly reduces the repelling force produced by longitudinal tip vibration. Torsional phaco is delivered with a special Ozil handpiece that creates torsional tip vibration at 32,000 times per second.

Besides the reduction in chatter and improved tissue followability, there are several other advantages to this modality. With axial vibration of the phaco tip, tissue is only cut during the forward stroke of the tip. With side-to-side vibration tissue is cut with every direction of tip movement, which increases the speed and efficiency of nuclear emulsification. Torsional phaco also creates disproportionately more movement of the phaco tip relative to the phaco needle shaft. The ratio is approximately 3:1 as compared to the 1:1 ratio of tip versus shaft movement with longitudinal vibration. This relationship reduces the amount of incisional heat generated by movement of the phaco needle shaft. AMO’s Signature Ellips was the second non-longitudinal phaco modality to be introduced. The tip moves in a transverse elliptical path that combines with some axial movement. This provides similar benefits to Ozil with a straight phaco tip.

Choosing phaco tips for chopping

Among the basic options for phaco tips, there are different shapes (straight vs. Kelman curved), different calibers (standard 19-gauge vs. micro 20-gauge), and different bevel angulations (0, 15, 30, and 45 degrees). There are specialty tips (e.g., diamond-shaped tip, Gravlee tip) that feature improved cutting ability and sharpness as well. The Dewey radius phaco tip (Microsurgical Technologies) has rounded edges to reduce the danger of capsule laceration. Tip designs to reduce surge, such as Alcon’s flare tip and ABS tip, were discussed in the previous chapter [13-15]. Each of these different tip configurations has pros and cons depending on the intraoperative situation. However, unlike other parameters, such as flow rate, vacuum level, phaco power, and power modulation, the phaco tip is the only variable that cannot be easily changed during the case. Therefore, one must compromise in choosing characteristics that would be alternately advantageous and disadvantageous at different stages of the procedure.

Standard vs. Micro tips

The first consideration is the size of the needle. It is helpful to separately consider the width of the shaft apart from the size of the tip opening. This is because the same shaft size can be paired with a smaller (zero degree bevel) or larger (30 degree tip) area opening in the tip.

Compared to the standard tip, a 20-gauge micro needle has a narrower lumen that restricts flow [16]. The increased fluid resistance reduces surge, and prevents material from rushing in as fast as through a standard diameter needle shaft. Slowing things down in this way helps when one wants to carefully control what enters the tip. This is important as one aspirates epinucleus, or thin, crumbling pieces of soft nucleus in the periphery of the bag. However, like drinking a milkshake through a cocktail straw, using a micro tip can seem painfully sluggish when large chunks of nucleus need to be evacuated.

The size of the phaco tip opening also influences performance. While 19-gauge phaco needles have larger tip openings than 20-gauge needles, it is also possible to increase the surface area of the tip's mouth by going from a zero or 15-degree bevel to a 30-degree bevel. A flare tip goes even further in combining the advantages of a large mouth with a narrower shaft.

At any given vacuum level, a larger mouth provides more holding power than a smaller mouth. Gripping strength is therefore proportionate to the surface area of the tip. A wider opening is also better for followability. Like a larger baseball glove, a big mouth can better catch particles as they tumble toward the tip. Mobile lens tissue can more readily mold into a larger opening, resulting in quicker occlusion. Thus, chatter and reduced holding power are the liabilities of a smaller tip opening. These disadvantages can be offset by chopping mobile nuclear fragments into smaller pieces, and by utilizing hyper-pulse mode or torsional phaco to diminish chatter.

There are, however, significant advantages to a smaller sized mouth. Like a narrower profile spike, a micro tip can more easily penetrate and incise a brunescent nucleus for vertical chop. Because a smaller phaco tip reduces particle size within the emulsate, downstream clogging of the aspiration line is less likely. Finally, one also has greater selective control over what tissue can enter a small tip. Surgeons prefer a 0.3 mm port instead of a 0.5 mm port for cortical aspiration because it is easier to avoid ensnaring the capsule with the smaller opening. The same principle holds for using the phaco tip to aspirate epinucleus or thin nuclear fragments abutting the posterior capsule.

The most impressive advantage of a small tip opening is the ability to occlude the tip with minimal tissue penetration. The larger the tip surface area, the more deeply the entire tip must be embedded to create a vacuum seal. If one is trying to elevate a thin, soft segment of nucleus out of the peripheral bag, this is a disadvantage. If part of the fragment crumbles apart, one may need to penetrate dangerously close to the capsule to occlude the tip. In contrast, a small mouth tip needs only to penetrate superficially before the entire opening is embedded enough to build vacuum. This allows one to pluck soft, thin pieces from the periphery with diminished risk of over-penetration.

In conclusion, smaller gauge phaco tips reduce the incidence of clogged tubing, more easily penetrate dense nuclei, and are easier to maneuver and occlude. By restricting flow, they reduce surge and prevent overly abrupt tissue aspiration. This combines with the smaller tip opening to provide greater selective control over what and how much tissue enters the mouth. However, these gains in safety come at the expense of reduced holding power and sluggish evacuation of large blocks of nucleus. Each surgeon must therefore prioritize which, among these characteristics is most important.

If one uses a 20-gauge phaco needle, one should employ a 30-degree rather than a zero degree tip. The latter is simply too small an opening when paired with a micro tip. Compared to the parameters for a standard 19-gauge tip, one must raise the aspiration flow rate to offset the more restrictive lumen size. One must also increase the vacuum to compensate for reduced holding power from the smaller tip surface area. Using hyper-pulse (if available) can greatly improve the followability that is otherwise compromised by the small tip design. Finally, just as meat is cut into smaller pieces for a child, one should chop the nucleus into smaller fragments to better match the smaller tip diameter.

Phaco tip bevel

Besides the aforementioned issues of the surface area of the opening, the phaco tip bevel design also impacts function. Using hydrophone experiments, William Fishkind has shown that during continuous ultrasound, an exit cone of cavitational micro bubbles streams away from the tip and is directed by the tip bevel. During sculpting, a bevel up 30-degree phaco tip is therefore aiming this stream of micro bubbles toward the endothelium. For chopping, orienting the bevel toward the flat surface of the nucleus produces a more rapid occlusion. Some surgeons initially impale with the tip oriented "bevel down" for this reason.

This author prefers to chop with the bevel facing to the right. This is because as the hemi-sections are laterally separated to propagate and complete the fracture, the phaco tip is always displacing the impaled portion to the right. Angling the bevel to the right takes full mechanical advantage of the longest portion of the tip. During fragment emulsification, particle turbulence is also directed by the bevel. For this reason, it may make sense to emulsify mobile particles with the bevel directed slightly sideways, rather than toward the cornea. As the posterior capsule becomes increasingly exposed, one can turn the bevel toward the cornea so that it is facing away from the capsule.

Fishkind's experiments also show that the curved Kelman tip directs cavitational energy downward, rather than forward. This correlates with the superiority of this tip design for sculpting. However, this curved tip is less well suited for chopping, particularly if the surgeon actively changes the direction of the bevel as described above.

Phacodynamic game plan for chopping

The following game plan integrates these various concepts into a unifying chopping paradigm for a peristaltic pump system. A separate memory setting is used to pre-set a package of parameters for each of the four phacodynamic objectives: sculpting (if needed), impaling/holding power, followability, and chamber maintenance.

Sculpting Memory Setting

Sculpting a partial trough or pit is helpful for brunescent nuclei, and as a transitional step to pure non-stop chopping. In the sculpting memory setting, one can use either continuous mode or a hyper-pulse mode. The power setting should be high enough so that the tip cuts, rather than displaces the nucleus. Cavitation helps in sculpting the deepest lamellae by reducing the requirement for tip penetration into tissue. Vacuum should be kept low (but not zero) in order to avoid an abrupt vacuum rise as the tip occludes in the periphery. Flow rate must be high enough to scavenge debris and to maintain clear visibility.

Impaling / Holding power Memory Setting

Single bursts of phaco and high vacuum combine to provide a maximally strong purchase of the nucleus. Maximal holding power is helpful for chopping and for elevating the initial fragments out of the capsular bag. Since burst mode is usually set at a high fixed panel power for impaling dense nuclei, it may be too powerful for softer nuclei. The highest vacuum level safely attainable (as determined by the surge test) is utilized for this stage. Flow rate is less important because so little tissue is removed.

Followability Memory Setting

Efficient emulsification of mobile, dense fragments requires a higher flow rate. Even though tip occlusion is usually partial during this stage, a high vacuum setting still increases the aspiration force, which can proportionately lower the amount of ultrasound required. One should therefore increase the flow rate from the preceding setting, and decrease the vacuum limit slightly. This offsetting vacuum reduction will prevent an increase in surge due to higher flow. This vacuum holding power will still suffice to chop and elevate the residual nucleus. For softer density nuclei, one should skip burst mode and perform all chopping with this memory setting.

With respect to power modulation, hyper-pulse reduces energy delivery, and improves followability by reducing the repelling cavitational forces from the tip. The resulting decrease in chatter and particle turbulence is most noticeable with dense nuclei, particularly if a micro phaco tip is used. Torsional phaco, if available, is ideally suited for enhancing followability of dense nuclear material.

Chamber stability / Epinucleus Memory Setting

Even slight post occlusion surge is unacceptable at this stage where the posterior capsule is exposed to the phaco needle. Therefore the vacuum should be significantly reduced for this step. This allows a slightly higher flow rate to be employed for epinuclear aspiration. Linear control of vacuum in foot pedal position 2 provides even greater control for this step in which the phaco needle is used primarily for aspiration. One can switch to this setting as the final sharp fragments of a dense nucleus are being removed. Alternatively, for very soft nuclei, one can use this setting for the entire case. This is because these nuclei more resemble the epinucleus in their consistency and behavior.

Appendix 2: (Chang)

Surgical Instrumentation:

Dr. Chang has no financial interest in any of the instruments listed below.

* **Chang Hydrodissection Cannula** 27-gauge

Katena K 7-5464 Short tip Katena 800-225-1195
Katena K 7-5466 Long tip (recommended for first-time user)
Mastel 800-657-8057
ASICO 630-986-8032 #AE-7638
Oasis Medical 800-528-9786 (Disposable) #4036 J
Rhein 800-637-4346 #91-8032

***Chang Combination Chopper** (horizontal microfinger chopper & sharpened vertical chopper)

Katena K3-2369 (to be held in left hand) [K3-2368 held in right hand]
Katena K3-2377 – Chang horizontal microfinger chopper only
ASICO 630-986-8032 #AE-2573
Stronger Medical Instruments (Titanium version) 408-776-3722

***Chang-Seibel Combination Chopper** (Chang horizontal + Seibel vertical) held in left hand
Katena K3-2341
Rhein 8-14564-R

***Chang Contingency Kit** (Katena) Katena 800-225-1195

21 G Bimanual Aspiration Handpiece	Katena K7-5811
21 G Bimanual Irrigation Handpiece	Katena K7-5840
22G Infusion Cannula, self-retaining	**Katena K7-6711**
Simcoe Irrigating Lens loop	Katena K7-5530 (R-handed surgeon)
Corbin Sub-Tenon's cannula	Katena K7-4008
Castroviejo Corneal Scissors	Katena K4-2220

***Packer Chang IOL Cutter 19G DFH-0012** Microsurgical technologies 888-279-3323
Use with Duet handles, Ahmed Micro-Grasper DFH-0011

<u>Chang Standard Cataract Instrument Set</u>

Adult Nasal Lid Speculum (locking) [# 99-122]	Pelion Surgical 866-701-2797
23G Graether irrigating collar button	Katena K3 4930
Fine Thornton 13 mm fixation ring	Katena K3 6161
Uthoff-Gills Scissors (capsule)	Katena K4-5126
Masket Capsulorrhexis Forceps	Katena K5-5084
Lester angled IOL Manipulator	Katena K3-2690

<u>Diamond Blades</u> Acutome 800-979-2020

2.5 / 2.8 trapezoid keratome – ask for Chang specifications
Lancet 1mm side port blade AK6175
Rubenstein AK 1.0 mm blade (preset 600 micron) AK6175P

<u>Special devices and instruments</u>

Mackool capsule retractors (disposable)	FCI Ophthalmics 800-932-4202
9-0 Prolene double armed, straight needle (x2)	FCI Ophthalmics
Cionni CTR	FCI Ophthalmics
4-0 Prolene iris retractors (autoclavable)	Katena K3-4970 (Also, Oasis and FCI)
Malyugin Ring	Microsurgical technologies 888-279-3323
Incision Gauge	Capitol Instruments #2000-01 206-271-3756
Vision Blue Dye	DORC 800-753-8824
Dewey Tip	Microsurgical technologies
Duet handles – micro forceps/scissors	Microsurgical technologies

To Chop Or Not To Chop - That Is The Question

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Divide and conquer is an excellent method of removing the cataract, however, it does require ultrasound energy for the original grooving and this energy utilization goes up dramatically with the hardness of the cataract. The time that ultrasound is on, is the most dangerous part of the surgical procedure, in that percentage wise, the complication rate is greatest with ultrasound on. In a recent survey of all complications at our institution,[1] 70% occurred while ultrasound was on, while the ultrasound itself is only on for 20-25% of the total procedure. This means, that for per second of use, it is at least 5 times more dangerous than the rest of the procedure! Needless to say, decreasing the amount of time we need to use something that is this dangerous should make the overall case safer. The harder the cataract, the greater the advantages of such an approach. Utilization of mechanical energy has proven to be much safer and not associated with corneal or capsular damage to the same extent as is ultrasound. Phaco-chop is simply an approach where mechanical energy is emphasized and ultrasound is minimized.

Phaco-chop itself first began with what is now called classical chop or horizontal chop. Horizontal chop entails using vector forces in parallel with the long axis of the lens to mechanically split the nucleus in two and then into multiple bite-sized chunks, only using ultrasound to assist aspiration. The ultimate in phaco-chop is using all mechanical forces by mashing the lens particles into the phaco tip, in which no ultrasound is used at all. This is very effective in such cases as Fuchs' corneal dystrophy.

While phaco-chop is a very forgiving procedure, it is important that core principles in phacoemulsification have already been mastered such as a routine intact capsulorhexis and a stable wound that results in good chamber maintenance without iris prolapse. Hydrodissection and hydrodelineation are also important positive features. The surgeon embarking in phaco-chop should reliably be able to rotate the nucleus prior to beginning phacoemulsification. The Chang cannula by Katena has been found by me to be superior in using the bent tip to engage the nucleus and absolutely guarantee that the rotation has occurred. These preliminary steps are all important in the actual procedure.

Classical Horizontal Chop:

The key in this step is to use the chopping instrument around the equator of the lens and the emulsification tip to impale the nucleus and then the chopping action occurs by bringing the chopper toward the emulsification tip, propagating a split and then a separation. This maneuver typically begins with the chopper going out underneath the capsulorhexis around the edge and then the phacoemulsification tip impaling the nucleus as near the wound as possible. The sleeve has to be drawn back at least a millimeter beyond the bevel and the nucleus should be impaled right up to the silicone sleeve. The chopping motion needs to be one with gentle posterior pressure so that you don't just scratch the surface of the lens. It is absolutely imperative that the chopper is hooked around the nucleus edge such that you can clearly see the nucleus splitting. As the chopper is brought to the phaco tip, if the chopper is in the left hand and the crack is propagating, then as the chopper comes near the phaco tip the left hand would move to the left and the phaco needle to the right so that the nucleus would be split completely in two. It is imperative that this split be complete and absolute on the first try in order to make this a simple step.

Some of the biggest problems people run into on this first step are not actively engaging the equator, because it is often much further out behind the capsule and iris than one might think. In a widely dilated pupil, you can actually see this maneuver, how often you have to feel this movement coming back around the nucleus. The second problem is not actively engaging the nucleus with the emulsification tip deeply enough so that you have adequate control of the nucleus. The chopping action itself is controlled between the two instruments and should not result in undue pressure on the zonules.

It is also helpful to have phacoemulsification equipment that has excellent fluidics such that high vacuum levels can be used to really control the nucleus and facilitate removal of the nuclear fragments. All modern phacoemulsification companies have options that allow excellent fluidics.

Once the nucleus is split in half, the next maneuver is to split off one segment of the hemi-nucleus. This is done by taking the chopping instrument carefully under the capsulorhexis flap around the equator and then engaging inside of the crack with the phacoemulsification tip into the hemi-nucleus that is to be chopped. Then removing a sliver somewhere between a fourth to a third of the hemi-nucleus. By aspirating on the apex of this fragment and allowing the suction to build, this fragment usually be easily removed, however, the chopping instrument can also be used like a finger to come around and dislodge that piece into the anterior chamber or to open the crack to assist aspiration, where it is easily removed. Once this step is done, then the rest of the procedure is very simple by taking the remainder of that hemi-nucleus and chopping 2 or 3 additional pieces which becomes increasingly easy in that there is more room, and then moving the other hemi-nucleus around 180 degrees and proceeding in a similar fashion to remove that hemi-nucleus.

As far as the number of pieces, certainly cutting the nucleus into four is adequate, however, chopping is so fast and it facilitates removing the pieces by ultrasound so that I will typically cut each nucleus into 8 pieces and with very hard nucleus, as many as 40-50 pieces. The chopping instrument is continually being used to feed and move the lens fragments and the better you get at this the less ultrasound you will use. Even very hard nuclei need have no more than a few seconds of effective phaco time to remove them efficiently and safely.

Currently the instrumentation I prefer is the Signature by AMO with Ellips FX technology. The Signature has excellent fluidics, which allows great control of the nuclear fragments. The phaco needle itself should be a straight needle in that angled needles tend not to hold as well and are difficult to use in a chopping maneuver until you gain more experience, then all tip configurations can work just fine. I often use a 0-degree tip, however, in that vertical chopping is an increasing part of my procedure, I also commonly use a 30 degree needle which provides a little better purchase of the material with vertical chop. My flow is typically 30 ml/min and my vacuum limit is 400 mm Hg.

Ellips FX is set at maximum excursion40% power, however, effective phaco power used is usually no more than 2- 3 seconds.

Key concerns raised regarding chop include difficulty in splitting the nucleus in two cleanly. Again, as long as the instruments are appropriately placed and the chopping instrument is moved such that there is slight posterior pressure and it is deep in the nucleus, routinely cleaving the nucleus in two is a very simple maneuver and will reliably occur in almost 100% of cases. The second piece is only a problem as long as it is not completely separated out so that it is still attached to the rest of the nucleus, and remember, you can use the second instrument to pry pieces out into the anterior chamber.

Other concerns have to do with coming on top of the anterior capsule and tearing zonules. Unfortunately this indeed can easily occur. The only solution is to always start on the central nucleus and then as you move peripherally, maintain a small amount of posterior pressure and you will always ride underneath the anterior capsule. Blindly reaching out peripherally in the chamber while trying to chop is dangerous and in order to be certain you are safe, you should look carefully for unusual wrinkles or lines in the capsule indicating you may have done this. Getting in the habit of always starting centrally in the nucleus and moving peripherally with posterior pressure should make such a complication impossible.

Many are also concerned about classical chopping often being out of sight in an area where the capsule can be broken. Excellent chop instruments are exquisitely safe on the capsule and can even be used to retract the capsule, which I routinely do between the phaco needle and the capsule at the end of the case, when the epi-nucleus is being removed. I have no royalty arrangement or financial interest, however, I use an Olson chopper designed by me, which is available from ASICO for phaco horizontal chopping and a vertical chopper of my design from Mastel Instruments.

The only other issue that comes up has to do with pieces that still interdigitate and, even though the chop seems to be complete, will not separate. This usually occurs from a relatively superficial chop and/or very hard nuclei. The horizontal chopper I designed is long enough to make this a very uncommon event. Recognizing this, however, usually allows a second chop or multiple chops until pieces can come loose, at which point, dissembling the lens is not a problem once you can see where the interdigitations are. In extremely hard nuclei, often there are fine woody connections that first require chopping and then using the chopper to separate all connections so the pieces are free and can be easily moved. Obviously the hardest of cataracts are the most challenging, however,. I would not even want to attempt them without some form of chop due to the efficiency of lens removal that results.

In summary, classical chop allows a very efficient disassembly of the cataract with minimal ultrasound time in a way that is not only efficient, but ultimately I feel is safer due to the minimization of ultrasound. Core principles outlined should make this a straight forward approach.

OLSON APPENDIX PAGE

1. randallj.olson@hsc.utah.edu

2. Instruments mentioned:

Olson Horizontal Chopper
ASICO 1-800-628-2879
Phacoemulsification Instrument
Abbott Medical Optics Signature
Santa Ana , CA

(I am a consultant for AMO but have no direct financial interest)

I particularly enjoy Signature due to the White Star and Ellips technology, which allows me increased followability, and minimal risk of wound burn even when using microphaco. The fluidics are excellent with superb control of the anterior chamber even at very high vacuum settings.

3. Settings for Signature :
400 mm Hg and 30 ml per minute flow with Ellips FX at 40% power.
Irrigation/Aspiration:
500 mm Hg vacuum limit 26 ml per minute flow.
For viscoelastic removal:
40 ml per minute of flow and 500 mm Hg vacuum limit.
For Microphaco 21 gauge technology
22 ml per minute of flow with the IV bottle on an extender as high as the tubing will allow.
Vacuum limit 250 ml per minute power with White Star one-third on two-thirds off at 50% power.

4. Recommended books:

Chang DF. Phaco Chop: Mastering Techniques, Optimizing Technology, and Avoiding Complications, Slack, 2004.
Fishkind WJ Complications in phacoemulsification, avoidance, recognition and management. Thiene NY 2002.

Vertical Phaco "Quick-Chop"

Louis D. "Skip" Nichamin, M.D.

Since the introduction of traditional (horizontal) phaco chop by Dr. Kunihiro Nagahara, many variations have been described. One important refinement has been the introduction of vertical chopping, a technique that has also been referred to as phaco "quick-chop," a term coined by David Dillman of Danville, IL. Actually, this variation was described contemporaneously by several authors including Neuhann of Germany, Vasavada of India, and Pfiefer of Slovenia. Dr. Fukasaku's snap and split variation, which is quite similar, may in fact represent the first iteration of this approach. The modification that these techniques share in common involves the location and placement of the manual chop instrument; rather than making an excursion out to and around the equator of the lens, the manipulator is pressed down onto the central anterior surface of the nucleus, at a point just in front of or to the side of the impaled phaco tip. Again, this approach is synonymous with vertical chop.

In recent years, the differentiation between chop techniques has become less distinct as many surgeons have come to integrate traditional horizontal chop with vertical quick-chop, as both approaches may be employed in a single given case. By way of historical significance, vertical chop arose (due to real and/or perceived) difficulties that some surgeons experienced when performing traditional phaco chop, as placement of the chop instrument peripherally and under the anterior capsule could be awkward and not well visualized. The subtle refinement of vertical quick-chop permitted better visualization and has proven to be an efficient disassembly technique for soft, medium, as well as dense lenses. It, furthermore, lends itself well to small pupil cases and in eyes where a generous capsulorhexis cannot be obtained.

In the procedure, the central nucleus is impaled deeply using short bursts or pulses of modulated phaco energy along with a steep angle of attack into the central lens substance. It helps to retract the silicone sleeve, exposing more of the metal needle, in order to maximize a deep purchase. The chop instrument is then placed just in front of or to the side of the buried phaco needle. Using the side-port incision as a fulcrum, the distal tip of the chop instrument is then pressed downward, assertively, into the nucleus as the phaco tip provides countertraction and a small degree of upward movement. As the cleavage plane is created, the chop instrument and phaco tip are spread apart laterally, propagating the division entirely across the nucleus from one pole to the other, as well as down and through the posterior nuclear plate. It is extremely important to verify that each successive cleavage plane is completely through and through the lens. One should not progress to the next chop unless this has been carefully verified.

The lens is then rotated, reimpaled, and the vertical down chop repeated. As lens density increases, a greater number of cleavage planes should be created. Some surgeons prefer to remove each chopped segment as it is created, while others will chop the entire cataract in situ and then remove all of the cleaved sections. To facilitate purchase and removal of a chopped segment, the manipulator is used to push the nuclear segment out toward the fornix of the capsular bag, causing the posterior apical portion of the chopped segment to present upward for easier purchase with the phaco tip. Higher levels of vacuum and flow are used to evacuate these segments, aided further by short microbursts of (hyper) pulsed phaco energy to collapse the nuclear material into the phaco tip. Purchase of chopped segments may also be facilitated by rotating the phaco instrument around its long axis to allow parallel alignment of the needle's bevel with the surface or facet of the nuclear segment, thus improving occlusion. As the purchased nuclear segment is drawn centrally from the capsular fornix, it may be further subdivided utilizing traditional (horizontal) maneuvers creating small bite-sized fragments which are more easily aspirated.

Several additional points should be stressed. As with any endocapsular technique, complete and effective hydrodissection is needed. An optional step is hydrodelineation. I personally utilize this maneuver in order to create a concentric division plane between the hard inner endonucleus and the soft outer epinucleus. Working within the confines of the epinucleus potentially increases safety. Also, chopping of an endonucleus allows for creation of smaller segments of nucleus which make subsequent purchase and removal easier. Evacuation of the epinucleus is performed by gradually debulking and trimming the epinuclear rim until it spontaneously collapses upon itself and is aspirated with little, if any, phaco energy.

Choice of the chop instrument is also important. With the traditional Nagahara phaco chop method, many surgeons prefer using a chopper that incorporates a blunt or bulbous distal tip to increase safety when passing the instrument peripherally. With the more vertical phaco quick-chop technique, a more pointed, beveled or flattened tip will more easily impregnate itself into the lens material. My current instrument of choice is the Nichamin Quick Chopper II, manufactured by Rhein, model #8-14533 for very dense cataracts, and the Nichamin Nucleus Divider sold by Storz, model #E0726 for all other lens densities.

In summary, the addition of the vertical quick-chop technique has further enhanced the overall efficiency of modern nuclear disassembly, and like many surgeons, I personally employ both approaches throughout a given case; vertical quick-chop is particularly useful in creating the initial cleavage planes, obviating the need to make a peripheral excursion beneath the anterior capsular rim. Following creation of several division planes, fragments may then be more easily aspirated by passing the chop instrument around the segment's periphery and subdividing them utilizing a horizontal chop maneuver. Central sculpting is only performed on rock-hard cataracts in order to weaken the cone of the nucleus prior to chopping. Without a doubt, chopping's popularity has grown due to its inherent efficiency, and once mastered, its enhanced safety as a nuclear disassembly technique.

Instruments:

Nichamin Nucleus Divider
(Current instrument of choice for most lens densities)

Product #: E0726
No financial interest
Storz Instrument Co.
3365 Treecourt Industrial Blvd.
St. Louis, MO 63122
Phone: 800-325-9929

Nichamin Quick Chopper II
(Current instrument of choice for very dense nuclei)

Product #: 8-14533
No financial interest
Rhein Medical
5460 Beaumont Cnt. Blvd. Ste. 500
Tampa, FL 33634
Phone: 800-637-4346

Nichamin Triple Chopper
(Original design, employed for traditional horizontal chop)

Product #: 054038 and 08-14506
No financial interest
Rhein Medical
5460 Beaumont Cnt. Blvd.
Ste. 500
Tampa, FL 33634
Phone: 800-637-4346

Stellaris MICS Coaxial:

(Conventional Bottle Infusion)

MICS 1.8 Needle & sleeve
BL5112 Optimized stability vacuum pack (high flow)
BL5110 Premium vacuum phaco pack (low flow)
(BL5112 tubing is used in most cases except for rock hard cataracts, wherein BL5110 tubing is used to prevent obstructions with the latter).

Chop:

Vacuum - Dual Linear 0-550 mmHg
Ultrasound - 0-35%
Bottle Ht.- 130cm
Microburst - 4PD 4PI (average density lenses)
Pulse (for dense lenses) - 10pps

Sculpt (dense lenses only, prior to chop):

Vacuum - Dual Linear 0-70 mmHg
Ultrasound - 0-40%, continuous
Bottle Ht. - 100cm

I/A:

Vacuum - Dual Linear 0-550mmHg
Bottle Ht. - 100cm

Polish:

Vacuum - Dual Linear 0-10mmHg
Bottle Ht. - 70cm

I/A Minimal (fornix vacuuming):

Vacuum - Dual Linear 0-100mmHg
Bottle Ht. - 70cm

MICS Coaxial with active infusion pump pressure:

(The Digiflow System)

MICS 1.8 Needle & sleeve
BL5112 Optimized stability vacuum pack (high flow)
BL5110 Premium vacuum phaco pack (low flow)
(BL5112 tubing is used in most cases except for rock hard cataracts, wherein BL5110 tubing is used to prevent obstructions with the latter).

Chop:

Vacuum - Dual Linear 0-600mmHg
Air Infusion - 80mmHg
Bottle Ht. - 70cm
Ultrasound - 0-35%
- Microburst - 4PD 4PI (average density lenses)
- Pulsed (for dense lenses) - 10pps

Sculpt (dense lenses only, prior to chop):
Vacuum - Dual Linear 0-70mmHg
Air - 75mmHg
Bottle Ht. - 100cm
Ultrasound - 40%

I/A:
Vacuum - Dual Linear 0-600mmHg
Air - 60mmHg
Bottle Ht. - 60cm

Polish:
Vacuum - Dual Linear 0-10mmHg
Air - 48mmHg
Bottle Ht. - 60cm

I/A Minimal (fornix vacuuming):
Vacuum - 0-50mmHg
Air - 40mmHg
Bottle - 60cm

Vitrectomy Settings:
Vacuum 0-100mmHg
Air - 70mmHg
Bottle Ht. - 60cm
Vitrectomy Cutter - Max cpm

Six Tips on Hydrodissection Technique –

David F. Chang, MD

Because the topic of hydrodissection receives relatively little attention compared to phaco and IOL insertion techniques, I believe it is the most under-rated step of cataract surgery. A properly developed hydrodissection fluid wave must travel behind the nucleus along the internal posterior capsular surface. In addition to permitting endonuclear rotation, such a wave also facilitates epinuclear and cortical cleanup by loosening their adhesion to the capsule. There are several pearls that facilitate the attainment of these three important goals.

Tip # 1

One of the most common mistakes is to initiate hydrodissection while the anterior chamber is over-inflated with viscoelastic. Hydrodissection is easier if the eye is somewhat soft and the anterior chamber has been partially emptied. Of course, this condition is at odds with the preceding capsulorhexis step where a generous amount of viscoelastic is desirable.

Using viscoelastic to deepen the chamber and to flatten the anterior capsular convexity makes it much easier to control the developing capsulorhexis tear. However, by exerting downward pressure against the nucleus, overfilling the AC with viscoelastic increases the resistance that the posteriorly directed hydrodissection wave must overcome. By limiting the escape of injected fluid through the incision, it can also lead to excessive deepening of the AC during the hydrodissection maneuver.

It is therefore advisable to burp out some viscoelastic immediately prior to initiating hydrodissection. This can be accomplished by pressing the shaft of the hydrodissection cannula against the incision floor prior to the injection. Partially emptying the AC will permit the nucleus to rise anteriorly away from the posterior capsule upon separation.

Tip # 2

Fear of "blowing out" the capsule causes many residents to be overly timid with the injection pressure. Since the volume of fluid that can be injected into the anterior chamber is limited, it must be injected rather quickly and decisively in order to generate sufficient hydrostatic force. The force is proportional to the rate of flow and the cannula resistance. Either a #30 or #27 gauge cannula provides sufficient resistance to generate the necessary force. A 3 ml syringe is small enough to provide good tactile feedback regarding the rate of flow. Increasingly larger syringes provide less and less tactile feedback.

Tip # 3

Although it is possible to rupture the posterior capsule with hydrodissection, nuclear/capsular block is a prerequisite. As a dense nucleus elevates, it may totally seal off the capsulorhexis from below. This prevents any fluid from escaping the capsular bag, and continued infusion can inflate the bag enough to cause posterior capsule rupture. The surgeon may not be aware of this complication until he inserts the phaco tip. At this point, the high infusion pressure will expand the rent, and the nucleus will drop before or during the initial sculpting stroke.

To avoid this complication, the injection should be terminated once the nucleus "pops up". Resist the temptation to otherwise continue injecting until the hydrodissection wave has completely crossed behind the nucleus. Instead, stop and reposit the nucleus posteriorly - thus breaking the nuclear/capsular block - before continuing with a second injection wave.

Tip # 4

Howard Fine has taught us to orient the fluid stream along the inner capsular surface by tenting the anterior capsule slightly upward with the cannula tip[1]. A wave that hugs the inner capsular surface will produce a slower advancing fluid front with scalloped edges. These characteristics indicate the resistance that is encountered as the wave shears through the cortical capsular adhesions. If the wave moves so quickly that you can't track the advancing edge, this may indicate that hydrodelineation was achieved instead of hydrodissection. Hydrodelineation will permit endonuclear rotation, but the epinucleus and cortex will remain adherent to the capsular bag. Some surgeons have advised leaving your thumb off the plunger until the cannula tip is positioned properly. Otherwise, if even a tiny amount of fluid is trickling out, it may keep the tip from actually tenting up the capsule just prior to the definitive injection.

Because both hydrodissection and hydrodelineation will permit rotation of a moderately dense endonucleus, confirmation of proper hydrodissection comes only when the epinucleus and cortex are removed. A loosened epinucleus will flip when aspirated. If the anterior shelf keeps breaking off, a mobile epinucleus can be rotated to bring a fresh anterior shelf to the contraincisional quadrant. In contrast, an adherent epinucleus does nost rotate or flip, and the distally aspirated sections eventually break off. This leaves a proximal adherent remnant with nothing to grab onto and an increased risk of aspirating the posterior capsule with the phaco tip.

Dr. Fine has described the principle of cortical cleaving hydrodissection whereby the loosened cortex can be entirely aspirated with the phaco tip[1]. However, even if one chooses not to attempt this maneuver, the extent to which the cortex has been loosened becomes evident during conventional automated I&A. For example, a mailing label easily separates in one piece from its waxed paper backing. However, once applied to a cardboard box, it becomes difficult to remove as a single piece. After one strip prematurely shreds and breaks off, we must again struggle to regrasp a new area. The difference is in the strength of adhesion. The tendency of loosened cortex to come out easily in sheets, as opposed to small adherent strips, is particularly advantageous in the sub-incisional area. Again, the risk of aspirating or rupturing the posterior capsule is greater if the cortex remains strongly adherent.

Tip # 5

A hydrodissection wave frequently fails to travel completely across the posterior capsule. Given the importance of preferentially loosening the sub-incisional cortex, it is therefore logical to initiate the hydrodissection wave from the sub-incisional anterior capsular rim. A partially incomplete wave that started from the contra-incisional fornix will leave the sub-incisional cortex maximally adherent. I advocate a right-angle hydrodissection cannula tip because, like a right-angle I&A tip, this configuration can access the proximal 180 degrees of capsular rim. A straight cannula can access the distal 135 degrees of capsular rim, and a J-shaped cannula is limited to the sub-incisional 90 degrees of capsular rim.

Tip # 6

I prefer to sever the last remaining capsular attachments by using the cannula tip to rotate the nucleus within the bag prior to phaco. The above-mentioned short, right angle tip works well at engaging the peripheral anterior nuclear surface and rotating it with circular raking motions. Additional hydrodissection can be readily performed if needed. The Chang hydrodissection cannula (Katena, Mastel) has a dull point at the tip to further facilitate this maneuver. This reusable, 27-gauge cannula has a short right angle tip that has been flattened in order to create a slightly fan-shaped fluid stream, and to tightly appose the anterior capsular rim. A disposable version is available through Oasis.

Because we are limited to a single incision in phaco, cortical cleaving hydrodissection greatly facilitates removal of the nucleus, epinucleus, and cortex. Without rotation we can’t otherwise safely access sub-incisional nucleus and epinucleus. Overly adherent sub-incisional cortex carries increased risk. Therefore, successful hydrodissection improves our efficiency, reduces the risk of posterior capsular rupture, and by cleaving the cortical attachments, reduces the rate of posterior capsule opacification[2, 3]. By optimizing our technique and instrumentation we can reliably achieve these benefits on a consistent basis.