Optimizing Machine Settings for Chopping Techniques

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Machine settings—both ultrasound and aspiration—should be customized according to each surgeon’s equipment, technique, and experience. The same surgeon may also adjust machine parameters according to the density of the nucleus. Simply copying someone else’s settings without understanding the rationale may therefore be inappropriate. For example, the higher flow and vacuum settings of an experienced surgeon may be too aggressive for a novice. However, as phaco technology evolves, the expansive array of programming options can be intimidating. This chapter will review general concepts that should guide one making the transition to phaco chop using a peristaltic pump system.

Phacodynamics—The Four Objectives

How much benefit is derived from modifying and customizing 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. 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 multiple, preprogrammed memory settings and even dual linear systems, surgeons can now use the foot pedal to seamlessly alter these parameters intraoperatively.

Every phaco technique combines multiple maneuvers with different phacodynamic requirements. As a conceptual framework for understanding fluidic and ultrasound strategies, one should consider the following 4 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 share these same objectives. If possible, one should assign a separate phaco memory setting for each
optimizing fluidics for chopping

The first major area for parameter adjustment is pump fluidics. Of the peristaltic pump’s 2 aspiration variables, flow rate (measured in cc/min) governs 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 mm Hg) builds within the aspiration line in between the occluded phaco tip and the pump, and will not exceed a maximum programmed level called the vacuum limit. With a peristaltic pump, the vacuum level cannot rise to the maximum level until the tip is occluded with tissue. Clinically, vacuum determines the strength with which the phaco tip grips nuclear material. The vacuum could be increased if the pieces keep falling off.

Objective 1: Sculpting Efficiency—Fluidics

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 does not become embedded within the nucleus (Figure 9-1). This prevents the vacuum level from rising. Aspiration flow helps to keep the tip path clear of debris, which improves visibility. Eventually, the tip slows down and must submerge into the peripheral lens as it passes beneath the capsulorrhexis edge. At this point, particularly with soft lenses, a sudden rise in vacuum can cause the peripheral nucleus and equatorial capsular bag to rush into the tip. For this reason, one should operate on a 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 3 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 and 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 2 maneuvers, the key fluidic attribute is holding power. For the last maneuver, followability and chamber stability are the primary objectives. As stated earlier, these 3 objectives assume different priorities during the course of the case.
Objective 2: Holding Power—Fluidics

During a chop, the phaco tip performs 2 distinct maneuvers that are facilitated by high vacuum. First, the tip impales the nucleus to immobilize it against the incoming chop (Figure 9-2). 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 hemisection from the other (Figure 9-3). 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 (Figure 9-4).

Objective 3: Followability—Fluidics

The third and final maneuver is scavenging and emulsifying the mobile chopped fragments (Figure 9-5). By increasing the force by which material is pulled through the tip, higher vacuum levels decrease the requirement for phaco energy during this stage. However, because the tip is frequently unoccluded or partially occluded, flow rate is more important here. A higher flow rate helps 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 there is continuing difficulty engaging mobilized fragments or if it seems as though the phaco tip must repeatedly chase pieces into the periphery, the flow rate might be too low and may need to be increased.

Objective 4: Chamber Stability—Fluidics

As progressively more of the nucleus is removed, the posterior capsule becomes increasingly 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, or if the zonules are lax. Since holding power is unnecessary at this stage, high vacuum becomes a liability and should be lowered to eliminate any chance of surge (Figure 9-6). This lower vacuum...
setting will also be appropriate for the epinucleus and for soft nuclei, where holding power is less important.

**Post-Occlusion Surge**

As stated earlier, high vacuum provides 2 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 drawn 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 into 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 chamber.

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

At the same machine settings, nuclear density and the phaco method 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 (see Figure 9-4). These partial occlusions generate fewer instances of surge because maximum vacuum levels are not reached.

**Surge Prevention Strategies**

Phaco machine manufacturers have devised numerous strategies for minimizing surge. The goal has been to provide surgeons with the advantages of high vacuum without the dangers posed by surge. One set of strategies addresses infusion. These range from bottle height extenders or irrigation tubing with increased lumen diameter, to forced infusion pumps available with combined anterior-posterior segment machines.

With respect to outflow, so-called “smart” pump technologies have been one of the most important innovations. The Millennium (Bausch + Lomb, Rochester, NY) was the first machine to offer dual linear foot pedal control over ultrasound and vacuum. Now available with the Stellaris (Bausch + Lomb) and the Signature in venturi mode (Abbott Medical Optics [AMO], Santa Ana, CA), this feature allows the surgeon to lower vacuum just prior to when the occlusion is about to break. The occlusion mode programming of the AMO Sovereign and Signature machines can automate a similar change in pump speed pre- and post-occlusion. Latest generation phaco machines use fluid venting to create an entirely closed, bubble-free aspiration system. Using microprocessors to monitor vacuum at remarkably frequent intervals, a dedicated onboard fluidic computer regulates the pump speed in order to minimize surge.

Another approach involves aspiration tubing where reducing the 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 “high vacuum” tubing or cassette.

A final set of surge-reducing strategies involve phaco tip design. The overall resistance to outflow is determined by the narrowest caliber lumen in the aspiration system, which is usually the internal diameter of the phaco needle. Micro phaco needles (21- or 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. Finally, the Alcon advanced bypass system (ABS) tip reduces surge by creating a shunt flow behind the occluded tip. This reduces air-
Determined the Vacuum Limit Through 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 their preferred “quadrant setting,” which is the vacuum limit used for quadrant emulsification in divide-and-conquer. With most of the nucleus still present, one holds an impaled nuclear fragment in the center of the pupil until the maximum vacuum setting is reached, identified by a beeping tone (Figure 9-7). Ultrasound is then applied. As the occlusion breaks, one gauges the amount of iris movement caused by any resulting 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 to 25%. By repeating this step, one will eventually discover an unacceptable amplitude of surge. At this point the maximum “safe” vacuum level has just been exceeded; 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 safely used for each of these steps.

Fluidics for Removing Epinucleus and Cortex

For epinucleus and cortex, the main fluidic objective is being able to aspirate lens material without ensnaring the capsule. Careful control of vacuum is the key. This 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 3 different vacuum levels during cortical clean-up. 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 does not ingest the cortex is needed (Figure 9-8). Finally, a high vacuum level safely evacuates the mobilized cortex once the aspirating port is safely facing the cornea and is located 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 (eg, to 50 mm Hg) to prevent aspirating the capsule. To draw the epinucleus centrally, one increases the vacuum hold (eg, 100 mm Hg) to avoid releasing it (Figure 9-9). Maximum vacuum (eg, 200 mm Hg) 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. Linear control of vacuum in foot pedal
position 2 allows the surgeon to continuously vary the vacuum levels with linear foot pedal control.

**OPTIMIZING ULTRASOUND FOR CHOPPING**

**Ultrasound Power**

All machines provide surgeons with linear control of ultrasound power in foot pedal position 3. This allows one to vary the power according to the density of each nucleus. 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. One hundred percent power means that the phaco tip is vibrating back and forth with maximum stroke length. Fifty percent power means that the axial needle stroke is only half as long.

While learning to sculpt, every surgeon recognizes that the higher the power, the better the tip cuts. This is because progressively more cavitation energy is created. However, this creates a corresponding tendency to use excessive power while emulsifying mobile fragments. Contrary to sculpting, the nucleus is not fixed and nuclear emulsification requires aspiration to pull the piece toward the tip. However, the greater the stroke length of the phaco tip, the greater the mechanical repelling force that will be generated. Thus, if one is experiencing poor followability when emulsifying a dense fragment, one should avoid the natural reflex 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 phaco tip stroke length that repels nuclear fragments.

In addition to creating greater repelling force, maximum power levels also generate the most frictional heat and cavitation 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 in foot pedal position 3. Clinically, there are 4 longitudinal phaco power modulations commonly used—continuous mode, burst mode, pulse mode, and hyperpulse mode. Torsional (Ozil, Alcon, Fort Worth, TX) and transverse (Ellips, AMO) and both nonlongitudinal phaco power modulations. All produce different tissue effects that can either facilitate or impede the phaco objective desired.

**Objective 1: Sculpting Efficiency—Continuous Mode**

Continuous mode is uninterrupted ultrasound and produces maximum cavitation energy. This mode is typically used for sculpting for this reason. Cavitation 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 posterior 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 heat and energy into the eye. As described below, hyperpulse—if available—can also be used for sculpting. Flow rate must be high enough to scavenge debris and maintain clear visibility (see the sidebar titled *Pearls for Sculpting Brunescence Nuclei*).

**Objective 2: Impaling/Holding Power—Burst Mode**

These powerful cavitation waves of continuous ultrasound are a distinct disadvantage when the surgeon is 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 toothpick only serves to weaken the purchase. With brunescent nuclei, a continuously vibrating phaco tip tends to core out a small cavity around the tip,
Pearls for Sculpting Brunescent Nuclei

When sculpting a large brunescent nucleus, excessive movement of the nucleus may weaken the zonules. The surgeon must therefore monitor whether excessive nuclear displacement is occurring during sculpting strokes. To address excessive movement, the surgeon should either increase ultrasound power, sculpt along a shallower path, or advance the tip more slowly. The surgeon must also recognize if a murky cloud of fluid appears in front of the tip. If enough retentive OVD admixes with brunescent nuclear material, the resulting sludge-like emulsate might occlude the phaco tip. This will usually occur when ultrasound commences, such as with sculpting. If the tip is completely blocked there can be no fluid outflow, and this will prevent any gravity fed inflow of irrigation fluid. The cessation of all fluid flow alongside a vibrating phaco needle will cause an immediate incision burn. The first warning sign of significant phaco tip occlusion during sculpting may be a cloud of milky emulsate, which is not immediately cleared by the obstructed aspiration line. Seeing this, the surgeon must stop immediately to assess whether there is any clogging of the aspiration line or phaco tip. Finally, with a brunescent lens, it is best to momentarily aspirate any OVD directly above the anterior lens surface prior to commencing sculpting in order to avoid this situation from occurring.

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 Diplomax (AMO). It is now available with most phaco equipment platforms. Burst mode is able to deliver a single momentary pulse of phaco energy. Bursts can be delivered individually or in rapid succession via surgeon foot pedal control. By embedding the tip without losing the surrounding tight seal, individual, successive bursts of phaco are ideal for impaling and gripping dense nuclear material for chopping (see Figures 9-2 and 9-3).

Burst mode delivers a fixed level of power that is preset on the machine console (panel control) rather than with the foot pedal. Therefore, this preset power should be varied according to the density of the nucleus. High power burst mode may be dangerous for soft nuclear sections in the bag; it may penetrate too aggressively if the power setting is too high.

Objective 3: Followability—Pulse Mode

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

In pulse mode, each pulse of phaco, or "on" time (ON-T), is followed by an equally long pause of "off" time (OFF-T). Compared to continuous mode (which is 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 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.

Hyperpulse Mode

In 2001, AMO introduced a new power modulation for the Sovereign machine called WhiteStar technology. This author first coined the term “hyperpulse” to convey the ability of dramatically increased pulse frequency to leverage the aforementioned advantages of pulse mode. Alternatively called ultrapulse, micropulse, or microburst, this technology is now offered with the AMO, Alcon, and Bausch + Lomb platforms.

Hyperpulse represents a paradigm shift from traditional pulse mode in 2 ways. First, it can be programmed at rates ranging from 30 to 100 pulses per second (pps). It is this rapid interruption and fragmentation of phaco time that reduces heat build-up at the tip. Cadaver studies have demonstrated that even with the irrigation clamped, the heat build-up remains below the clinical threshold for producing a wound burn. Most importantly, the pulses of phaco utilize traditional ultrasound with the full power continuum. Thus, there is no functional loss of cutting efficiency with brunescent tissue.

The second major enhancement introduced with hyperpulse was 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-T of continuous mode, pulse mode interrupts these “on” pulses with equally long rest periods of “off” time. Duty cycle expresses the percentage of time “on” and is equal to ON-T divided by (ON-T + OFF-T). The duty cycle for continuous mode is 100% and for pulse mode is 50%, indicating that pulse mode reduces ultrasound delivery by a factor of 2. This is true whether one uses 3 pps or 6 pps.
In hyperpulse mode, the duty cycle can be further varied by lengthening or shortening the rest periods. For example, a 6 m/sec phaco pulse with a 12 m/sec rest period creates a 33% duty cycle and 55 pps. A 24 m/sec rest period would create a 20% duty cycle and 33 pps. These settings are a dramatic departure from traditional pulse mode (eg, 4 pps = 125 m/sec pulse followed by a 125 m/sec rest = 50% duty cycle). The overall effect of hyperpulse with duty cycle reduction is to dramatically reduce heat and energy delivery without any loss of cutting efficiency.13,14,16 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.

Nonlongitudinal Phaco

Arguably the most important advance in ultrasound technology during the past decade was Alcon’s torsional phaco.18-28 Dubbed “Ozil,” this technology utilizes oscillating, rotational movement of the phaco tip in place of longitudinal strokes. To generate cutting action, a bent tip—such as a Kelman tip or one of several variations—is used. This utilizes mechanical action rather than cavitation to cut nuclear material. Compared to axial tip movement, torsional phaco provides the efficiency of cutting with oscillatory movements in both directions. AMO was the next company to introduce its nonlongitudinal technology and called it transversal ultrasound, or “Ellips,” during which an elliptical movement of the phaco tip is created. Because the tip movement traces an ellipse along with some slight longitudinal motion, a straight phaco tip can be employed (see Figure 9-5). There are several major benefits to nonlongitudinal phaco. The ability of the tip to cut throughout its entire cycle of movement improves cutting efficiency and reduces ultrasound time.18-22 As with a lower duty cycle, this reduction in ultrasound energy reduces heating of the incision.23,24,28 There is also a dramatic reduction in repelling force associated with a purely axial movement of the phaco tip.25 As a result, chatter that is normally seen with brunescent fragments is significantly diminished.19 This not only improves followability, but also lessens endothelial cell trauma caused by particle turbulence at the tip.18-20 While burst mode is still effective for impaling dense nuclei during chopping, nonlongitudinal phaco is ideal for emulsifying mobile fragments (see Figure 9-6).

Effective Phaco Time

The ability to dynamically adjust phaco power and change power modulations creates tremendous variability in ultrasound delivery 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 phaco time (100% duty cycle) using 25% power would give a 30 second EPT (120 s ÷ 4). Switching to pulse mode (50% duty cycle) would have further cut the EPT in half (15 seconds). Hyperpulse with a 33% duty cycle would have cut the EPT by one third (10 seconds).

EPT is primarily affected by the power level used. Since there is no industry-wide standard for measuring stroke length, EPTs cannot be used to accurately compare machine performance from 2 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 (hyperpulse versus traditional pulse or continuous mode). EPT can also be used to compare the performance of new machines with predecessors from the same manufacturer.

Choosing Phaco Tips for Chopping

Among the basic options for phaco tips, there are different shapes (straight versus Kelman curved), different calibers (standard 19-gauge versus micro 21- or 20-gauge), and different tip bevel angulations (0, 15, 30, and 45 degrees). There are specialty tips (eg, diamond-shaped tip or Dewey rounded edge tip) that improve cutting ability or alter sharpness as well. Designs to reduce surge, such as the flare tip and the ABS tip, were discussed previously. Each of these different tip configurations may be associated with advantages or disadvantages depending on the situation. However, unlike other parameters such as flow rate, vacuum level, phaco power, and power mode, the tip is the only variable that cannot be easily changed during the case. Therefore, one must compromise in choosing characteristics that might be alternately advantageous or disadvantageous at different stages of the procedure.

Standard Versus 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 (0 degree bevel) or larger (30 degree tip) area opening in the tip.

Compared to the standard 19-gauge tip, a 20-gauge micro needle has a narrower lumen that restricts flow.2 The increased fluid resistance reduces surge and prevents material from rushing in as fast compared to 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 during aspiration of the epinucleus or when aspirating the thin, crumbling pieces of soft nucleus in 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 0 or 15-degree bevel to a 30-degree bevel. A flare tip goes even further in combining the advantages of a large surface area mouth with a narrower shaft.3,4

Gripping strength is proportionate to the surface area of the tip opening. At any given vacuum level, a larger mouth provides more holding power than a smaller mouth. 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. 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.

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 line is less likely. Finally, one also has greater 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 (see Figure 9-6). 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 would only need 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 overpenetration.

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. The smaller tip opening provides greater selective control over what and how much tissue enters the mouth, which is also an advantage. 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 0 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 hyperpulse with reduced duty cycles or torsional or transversal ultrasound 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 size of the tip. These measures allow surgeons to enjoy the greater safety of smaller phaco tips without noticeably sacrificing speed and efficiency. Of all the variables discussed, going from a standard 19-gauge to a 20-gauge phaco tip may yield the single biggest improvement in posterior capsule rupture rate. The smaller tip is therefore strongly encouraged for residents and surgeons transitioning to phaco chop.

**Phaco Tip—Bevel**

Besides the aforementioned issues of the surface area of the opening, the bevel design also impacts function.29 Using hydrophone experiments, William J. Fishkind, MD, FACS has shown that during continuous ultrasound, an exit cone of cavitational micro bubbles streams from the tip in the direction of the tip bevel.30 During sculpting, a 30-degree tip used bevel up is therefore directing this stream of micro bubbles toward the endothelium. For chopping, as discussed in Chapter 8, orienting the bevel toward the flat surface of the nucleus produces a more rapid occlusion (Figure 9-10A and 9-10B). Some surgeons initially impale with the tip oriented bevel down for this reason.31

This author prefers to chop with the bevel facing to the right. This is because as the hemisections are laterally separated to propagate and complete the fracture, the phaco tip is always displacing the impaled portion to the right (see Figure 9-3). 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 sharply curved tip is less well suited for chopping, particularly if the surgeon actively changes the direction of the bevel as described above.
The following game plan integrates these concepts into a unifying chopping paradigm for a peristaltic pump system. A separate memory setting is used to preset a package of parameters for each of the 4 phacodynamic objectives: sculpting (if needed), impaling/holding power, followability, and chamber maintenance. In addition, the entire set of parameters can be made slightly more or less aggressive according to differing nuclear density. Many machine platforms allow surgeons to preprogram different parameters for each of these memory settings according to nuclear density (Grades 1 through 4), that can then be altered with a single button function.32

**Sculpting Memory Setting**

As discussed in Chapters 4 and 5, sculpting a partial trench or pit is helpful for brunescent nuclei and is a transitional step to pure nonstop chopping. In the sculpting memory setting, one can use either continuous mode or a hyperpulse mode. The power setting should be high enough so that the tip cuts, rather than pushes the nucleus. Cavitation helps in sculpting the deepest lamellae by reducing the requirement for tip penetration. Vacuum should be kept low (but not 0) in order to avoid an abrupt vacuum rise as the tip occludes in the periphery (see Figure 9-1). Flow rate must be high enough to scavenge debris and maintain clear visibility.

**Impaling / Holding Power Memory Setting**

Burst mode and high vacuum combine to provide a maximally strong purchase of the nucleus. Holding power is helpful for chopping and for elevating the initial fragments out of the capsular bag (see Figures 9-2, 9-3, and 9-4). Since burst mode needs to be set at a high fixed panel power for impaling dense nuclei, the power for burst mode should be lowered for soft-medium 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 the occlusions are 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 slightly33 (see Figure 9-6). This offsetting vacuum reduction will prevent an increase in surge due to higher flow. The lower vacuum holding power will still suffice to chop and elevate the residual nucleus (see Figure 9-6).

With respect to power modulation, nonlongitudinal phaco reduces energy delivery and improves followability by minimizing the repelling cavitation forces from the tip. The resulting decrease in chatter and particle turbulence is most noticeable with dense nuclei, particularly if a micro...
tip is used. To reduce the duty cycle, traditional pulse mode or hyperpulse can be paired with nonlongitudinal phaco.

**Chamber Stability/Epinucleus Memory Setting**

Even slight post-occlusion surge is unacceptable when the posterior capsule is exposed to the phaco needle, so vacuum should be significantly reduced for this step. This allows a slightly higher flow rate to be employed for epinuclear aspiration (see Figure 9-9). Linear control of vacuum in foot pedal position 2 provides even greater control as 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 very soft nuclei more resemble the epinucleus in their consistency and behavior.

**MACHINE-SPECIFIC RECOMMENDATIONS**

Modern phaco machine platforms offer an ever-expanding array of fluidic and power modulation options that specifically benefit chopping. The availability of so many innovative choices and features creates a double-edge sword. While this permits a degree of phacodynamic customization that was never before possible, it also requires the surgeon to comprehend and preprogram an intimidating number of variables. In other words, such progress comes at the expense of simplicity.

The next 3 chapters are intended to help the reader configure a chopping program for his or her specific phaco machine. Individual chapters cover the 3 most popular machine platforms in North America (in alphabetical order)—the Alcon Infiniti, the AMO Signature, and the Bausch + Lomb Stellaris. These chapters are not intended to be a shopper’s guide to buying a new machine. Rather, the goal is to help users understand the unique options available with their machine for chopping and to provide them with a starting point for configuring and later customizing their personal parameters. Although sample programs differ from one machine to the next, each is based upon the principles discussed in the current and preceding chapters.

**REFERENCES**


