As part of its ongoing commitment to education, ASCRS presented “Phaco Fundamentals: How Well Do You Know Your Machine?” at the 2015 ASCRS•ASOA Symposium & Congress in April. The program was moderated by David F. Chang, MD, clinical professor of ophthalmology, University of California, San Francisco, and Elizabeth Yeu, MD, assistant professor, Eastern Virginia Medical School, and in private practice, Virginia Eye Consultants, Norfolk, Va.

Phaco experts covered key principles for optimizing fluids and power modulation for different stages of nuclear removal in standard, complex, and femto phaco cataract cases.

“Optimizing machine settings is an important factor in successful cataract surgery, but it is often overlooked or underemphasized in phaco education,” Dr. Chang said. “Nowadays, surgeons can individualize pre-packaged settings of power modulation and fluids for each stage of nuclear removal. However, the surgeon must understand the principles for how to optimize the power and fluidic settings for different objectives.”

Phaco vocabulary
Berdine M. Burger, MD, Carolina Eyecare Physicians, Charleston, S.C., reviewed key terms related to phacodynamics and fluids.

Phacoemulsification technology combines the power to break up the cataract and fluids to maintain the chamber and safely remove the cataract. “The emulsification power is the stroke length times the ultrasound frequency,” she said. The frequency—burst, pulse, or hyperpulse—is a set

Accreditation Statement
This activity has been planned and implemented in accordance with the Essential Areas and policies of the Accreditation Council for Continuing Medical Education through the joint providership of the American Society of Cataract & Refractive Surgery (ASCRS) and EyeWorld. ASCRS is accredited by the ACCME to provide continuing medical education for physicians.

Educational Objectives
Ophthalmologists who participate in this activity will:
• Modify and customize platform-specific phaco settings to maximize outcomes for routine cataract surgery cases and identify the process for refining the learner’s own settings over time;
• Identify specific details of how phacodynamics technology function; and
• Define the platform-specific technology settings and clinical procedure pearls for successfully navigating common phaco complications and surgical issues.

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Berdine M. Burger, MD, has been a member of the speakers bureaus of Abbott Medical Optics Inc. and Genzyme.

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As fluidics and ultrasound priorities evolve during the stages of phacoemulsification, it is essential to understand the phacodynamics of the process.

Phacoemulsification machines must be powerful enough to remove cataracts, but the anterior chamber must remain stable. “We need to prevent surge, and we always want to minimize damage to the cornea and decrease heat production,” said Bonnie An Henderson, MD, clinical professor of ophthalmology, Tufts University School of Medicine, and in private practice with Ophthalmic Consultants of Boston.

**Peristaltic versus venturi pumps**

Phacoemulsification systems rely on peristaltic and venturi pumps. Peristaltic pumps enable surgeons to set vacuum limits independent of flow (Figure 1). “You can access high vacuum limits and have a moderate flow and low vacuum, so you can have greater safety with thermal production,” she said. However, surgeons need to understand what is happening so they can adjust flow and vacuum separately.

“The venturi pump is not occlusion dependent, so you can actually have vacuum without occluding the tip,” Dr. Henderson said (Figure 2).

The venturi pump can have a rapid rise time. Pieces follow the flow to the tip in the center of the eye and can be vacuumed without full occlusion. However, flow depends on the vacuum level.

Surge can be controlled with a higher bottle height, deepening the chamber, or with a reduced aspiration flow rate or vacuum preset. Some machines have automatic systems that help prevent surge or an aspiration bypass port allowing flow to continue when the tip is occluded, Dr. Henderson explained.

**Expert share phacodynamics fundamentals valuable to all cataract surgeons, regardless of their experience levels**

Our goal is to remove a cataract using enough power to be efficient, but not using more power than necessary.”

Lisa Park, MD

**Peristaltic pump vacuum and flow**

Flow pumps directly control flow and indirectly control intraocular pressure (IOP) and vacuum.

If there is no pump flow with an open-pin valve, the bottle height controls the IOP; when the flow pump starts, there is flow into the anterior chamber, which reduces the IOP in the anterior chamber, said Kenneth L. Cohen, MD, Sterling A. Barrett distinguished professor, Department of Ophthalmology, University of North Carolina at Chapel Hill.

At a low flow rate, IOP is reduced; the aspiration line pressure decreases. The differential between the 2 pressures moves the fluid, he explained.

When flow increases, IOP decreases more, and a negative pressure, vacuum, occurs in the aspiration line, increasing this differential.

With partial occlusion, the flow decreases into the anterior chamber.
chamber and IOP increases even with the same pump rotation, increasing the vacuum in the aspiration flow line. With total occlusion, the IOP is mandated totally by the bottle height, and the vacuum reaches the maximum preset level.

Flow largely controls distal followability, Dr. Cohen said. The surgeon can increase the pump rate to bring pieces to the phaco tip or bring the aspiration port closer to the piece in foot position 2, increasing the effect of flow, he explained.

“Proximal followability is controlled mostly by vacuum and somewhat by flow,” he said. With partial occlusion, the flow in the anterior chamber decreases, but with the greater differential between the pressure in the anterior chamber and aspiration flow line some vacuum develops.

With a flow pump, surgeons perform partial occlusion phaco, or carouseling phaco, he said. “Initially we have occlusion of the phaco tip with the nuclear fragment in foot position 2, and the fragment is engaged. Then we go to foot position 3, and we have an ultrasound cycle, which partially breaks down the fragment.” There is some flow and some vacuum.

“When the phaco has partially broken it down, it aspirates the emulsate, and it gets the fragment to carousel with proximal followability into your phaco tip so that you now have occlusion, and this whole cycle can start again,” Dr. Cohen said.

Ultrasound modulation
“Our goal is to remove a cataract using enough power to be efficient, but not using more power than necessary,” said Lisa Park, MD, associate professor and associate director of residency training, Department of Ophthalmology, New York University School of Medicine. This reduces the risk of thermal injury, corneal swelling, and endothelial cell loss. Power modulation improves followability with less chatter, she explained.

Direction variables include longitudinal, transversal, and torsional phacoemulsification options. Timing includes continuous, pulse, and burst modes (Figure 3). The hyperpulse mode delivers more than 100 pulses per second, and hyperburst results in a burst duration of 4 ms.

“You would … change your settings according to the objective of what you’re trying to accomplish, and you’ll modify your setting according to the density of the nucleus you’re trying to remove,” Dr. Park said.

measurement on the machine. The foot pedal controls the stroke length, which may be longitudinal, transverse, or torsional.

Fluidics refers to inflow and outflow (Figure 1). “Your flow is your attraction to the phaco tip,” Dr. Burger said. Outflow has 2 components: aspiration of the material—the amount of flow through the tubing—and the vacuum, the attachment of the fragment to the tip.

Phacoemulsification units rely on 2 types of pumps—peristaltic and venturi (Figure 2). The peristaltic pump usually uses tubing to milk out the fluid. Vacuum is occlusion dependent and rises more slowly. “In the venturi system, a compressed air system, your vacuum is occlusion independent and will more rapidly rise,” she said. Most modern machines use software to mimic both.

“There’s an incredible power to very small and intentional adjustments to your settings in keeping patient satisfaction at that postoperative visit as high as possible,” Dr. Burger said.
Adjusting phacoemulsification settings during cataract surgery

**Average lens**

- **Bottle height**: –135 cm
- **Power**: –40
- **Vacuum**: –275
- **Pulse per second**: –30
- **Duty cycle**: –40%

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**Dense lens**

- **Bottle height**: –135 cm
- **Power**: –60
- **Vacuum**: –290
- **Pulse per second**: –70
- **Duty cycle**: –60%

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Fluidics and ultrasound priorities change during phacoemulsification, depending on whether the surgeon is sculpting, chopping, or emulsifying the remaining fragments of the nucleus.

Experts share how they modify their settings on 3 major platforms to meet their changing needs during surgery.

**Stellaris PC**

Bonnie An Henderson, MD, clinical professor of ophthalmology, Tufts University School of Medicine, and in private practice with Ophthalmic Consultants of Boston, shared her practices with the Stellaris PC (Bausch + Lomb, Bridgewater, N.J.), a venturi machine.

During sculpting, power is reduced to decrease thermal energy. As she sculptures, Dr. Henderson uses a bottle height of approximately 75 cm, which brings inflow into the eye. Her vacuum setting is 40 mm Hg; ultrasound, 50; pulses per second, 200; and duty cycle, 50%. “When you’re sculpting, you want to be able to move your phaco tip smoothly through the nucleus without much resistance,” she said.

During segment removal or chopping, she increases her inflow, setting the bottle height at 135 cm. The vacuum is approximately 275 mm Hg, providing greater holding force. “Every time you want to increase your vacuum, you should increase your inflow,” she said.

Ultrasound power settings are reduced because she does not need to break through and sculpt the nucleus. Her pulse per second rate and duty cycle are also reduced. Her bottle height is similar for average or dense cataracts, but she uses a slightly higher power and slightly increased vacuum for dense cataracts (Figure 1). “The pulse per second goes higher because I’m trying to emulsify the piece a little bit more and the duty cycle gets a little higher,” she said.

**WhiteStar Signature**

Although the WhiteStar Signature Phacoemulsification System (Abbott Medical Optics, Abbott Park, Ill.) includes flow and venturi pump functions, Kenneth L. Cohen, MD, Sterling A. Barrett distinguished professor, Department of Ophthalmology, University of North Carolina at Chapel Hill, only uses the flow pump.

During the sculpt setting he uses for residents, the aspiration of flow rate and vacuum in the panel settings are fixed (Figure 2). Power has a linear setting controlled by the foot pedal.

With the impale setting for chopping, residents have a slightly higher aspiration flow rate than for sculpting. “The vacuum is set much higher in a panel setting because you want to hold the piece firmly for chopping,” he said. The power is linear to impale the nucleus.

The Ellips function, employing transversal energy, is used to emulsify the nuclear fragment. It is set with an occlusion mode, so aspiration flow rate is reduced as the vacuum increases. The aspiration flow rate and vacuum are linear, so they can be controlled with the foot pedal, he said.

**Infiniti and Centurion**

Lisa Park, MD, associate professor and associate director of residency training, Department of Ophthalmology, New York University School of Medicine, compared the Infiniti Vision System and Centurion Vision System (Alcon, Fort Worth, Texas).

When using the Infiniti for sculpting, vacuum and aspiration are low, she explained (Figure 3). However, during quadrant removal Dr. Park increases the vacuum and aspiration settings.

She decreases the phaco power when she moves to the epinucleus so she doesn’t eat through the pieces as quickly. In addition, she turns down the vacuum to hold the pieces more easily.

continued on page 5
Cataract surgeons can alter their phacoemulsification settings in complicated cases, such as intraoperative floppy iris syndrome (IFIS), brunescent cataracts, and soft posterior polar cataracts.

**Intraoperative floppy iris syndrome**

“One of the recent greater challenges for the cataract surgeon is the floppy iris patient,” said Lisa Park, MD, associate professor and associate director of residency training, Department of Ophthalmology, New York University School of Medicine. “The first thing I’m going to say is preparation is everything.”

A careful patient history is essential. The role of tamsulosin in IFIS has been widely discussed, but clinicians should also ask patients about other alpha-1 adrenergic blockers. “In women, terazosin and doxazosin that are being used for blood pressure have been implicated,” Dr. Park said.

She often stains with trypan blue in these cases. “I do this because if you’re going to run into a problem, it’s nice to make sure you can really see the capsule,” she said. Then she uses an Arshinoff shell. She uses a dispersive to protect the endothelium and cohesive beneath to push back the iris.

Dr. Park prefers to use a ring for IFIS cases. During phaco, she brings the pieces up and out rather than performing phaco in the bag. “My personal feeling is that when you have this floppy iris, everything flops,” she said.

Once she has observed a floppy iris, although she is working through a 2.2- or 2.4-mm wound, she closes the wound. “This can easily come up and out, and that can be a source of endophthalmitis, so I tend to close my wound in those cases,” she said.

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“Brunescent cataract”

A common question about phaco chopping is how to hold onto a lens fragment, said Bonnie An Henderson, MD, clinical professor of ophthalmology, Tufts University School of Medicine, and in private practice with Ophthalmic Consultants of Boston (Figure 1).

One way is to increase the vacuum. “But if you increase your vacuum, you have to make sure you’re keeping your chamber stable, so you want to think about increasing your bottle height or your inflow if you want to drastically increase your vacuum,” said...
Dr. Henderson, who presented a video using the Stellaris PC (Bausch + Lomb, Bridgewater, N.J.). “With the venturi system, you will notice that there is good movement of the pieces toward the tip and the pieces will engage before being fully occluded,” she said. “The biggest danger I think with working with a venturi system, especially with the brunescent cataracts, is that the pieces are opaque.” Therefore, it may be difficult to see the bottom of the phaco tip, and the surgeon could be vacuuming past the lens fragment and inadvertently into the posterior capsule, she explained. She recommended keeping a second instrument such as the chopper beneath the probe to protect the posterior capsule. She also changes her viscoelastic for brunescent cataracts. She uses a dispersive viscoelastic with chondroitin sulfate close to the cornea to protect the endothelium from the additional energy that is used in emulsifying a dense cataract.

Soft posterior polar cataract

Kenneth L. Cohen, MD, Sterling A. Barrett distinguished professor, Department of Ophthalmology, University of North Carolina at Chapel Hill, featured cases with soft nuclei performed by residents with the WhiteStar Signature Phacoemulsification System (Abbott Medical Optics, Abbott Park, Ill.) (Figure 2). In one posterior polar cataract, the surgeon performed only hydrodelineation. With the sculpt setting in foot position 2, a pocket was created to allow for fluid movement by removing OVD and anterior cortex and epinucleus. “We’re creating a pocket so we don’t get an incision burn,” he said.

Then a small groove was created in the small nucleus. The surgeon used the epinuclear setting, which provided linear control of vacuum and flow. “Once you do get occlusion, you can use your foot pedal to control the level of vacuum to basically aspirate this soft cataract,” he said.

The remaining large, thick epinucleus was removed using the linear function on the foot pedal and foot position 2, with no phaco power, just linear aspiration. The linear vacuum trimmed the anterior edge of the epinucleus, and the surgeon brought it forward with the Seibel nucleus rotator/horizontal chopper.

There was enough room for the posterior polar cataract to rotate and move to another edge. The occlusion mode was also used, which lowers the aspiration flow rate as the vacuum rises, Dr. Cohen explained.

He presented a case of posterior subcapsular cataract, for which hydrodissection and hydrodelineation were used. The surgeon removed the OVD and aspirated as much cortex and epinucleus as possible to get to the nucleus. A small groove was sculpted, and using a Drysdale, the lens was rotated.

Using the epinuclear setting, set on linear aspiration and linear vacuum, the surgeon removed the anterior rim of the epinucleus until the cataract could be flipped and then removed with occlusion mode phaco, which automatically lowers the aspiration flow rate as the vacuum rises. “Very safe, essentially using no phaco,” he said.
Phacoemulsification settings for laser-assisted cataract surgery: Fluidics and pearls for success

As cataract surgery technology evolves, surgeons making the transition to femto laser cataract surgery need to know how to adapt their phaco settings for venturi and peristaltic pumps for femto phaco.

**Venturi settings**
Keith A. Walter, MD, professor of ophthalmology, Wake Forest University, Winston-Salem, N.C., compared the features of the LenSx Laser System (Alcon, Fort Worth, Texas) and Catalys Precision Laser System (Abbott Medical Optics, Abbott Park, Ill.).

Surgeons can choose either a segmentation or cube option with LenSx or both options simultaneously with Catalys, he said. “The Catalys goes out beyond the capsulotomy for your complete lens fragmentation and making the cubes,” he said. “LenSx has a limit on how far out you can go based on the capsulotomy size.”

Femtosecond cases rotate and crack more easily, Dr. Walter said. “There’s a little bubble layer that forms behind the lens in the Catalys cases between the epinucleus and cortex that makes that lens automatically rotate every time,” he said. Because of the bubble layer, surgeons do not need to manage an epinucleus.

With Catalys software, surgeons can customize their treatment, with segmentation and quadrants, sextants, and octants. “You can use softening patterns and change your cube size from 100 microns to 2,000 microns,” said. “I typically use 350 microns on most of my cases. If it’s a denser lens, I might go down to 250 microns.”

With this lens treatment, surgeons use less ultrasound and phacoemulsification and more fluids, he said.

Dr. Walter likes the Whitestar Signature System (Abbott Medical Optics) with dual pumps for femto-treated cases. “I think you need to have different pumps, depending on whether you want to hold a quadrant or try to grab a piece, versus venturi, where you want more followability for those small fragments.”

In a typical case, he uses the peristaltic mode for sculpting and to grab the first quadrant and may switch to venturi afterward. For a softer lens where he is working in the bag, he may remain in peristaltic mode.

With venturi, his goal is to prolapse the fractured nucleus out of the bag and allow the vacuum to do most of the work. “If you’re getting too much surge, you can always change your vacuum, or you can also use a larger tip.”

**Peristaltic extraction**
Elizabeth Yeu, MD, assistant professor, Eastern Virginia Medical School, and in private practice, Virginia Eye Consultants, Norfolk, Va., suggested the cross-chop/single cylinder pattern for those beginning with laser-assisted cataract surgery.

She explained that the chop/cylinder is useful for divide and conquer surgeons and for softer cataracts. With a supracapsular technique, surgeons can use a chop/cylinder or grid technique, she said.

“But as a chop surgeon, the waffle or the grid fragmentation pattern is wonderful,” Dr. Yeu said. “Of course, with the denser nuclei, it goes without saying, because there’s ultimately going to be less ultrasound energy that is being transmitted into the eye.”

Dr. Yeu shared a video demonstrating cross-chop with a single cylinder and utilizing a “pre-chop” setting before sculpting. The “pre-chop” setting has a slightly greater vacuum and less energy to first remove the central core delineated by the cylinder pattern. “When you debulk that cylinder, very little phaco is required, but it makes it easier to engage and split the rest of the nuclear pieces, and then you can go into your normal sculpt setting,” she said.

She uses a separate chop versus quad setting, with a linear burst and a fixed vacuum when she engages the nucleus. “I want to hold on really well, but I want to continue holding on without cheese-wiring through, so having that off time gives me the control to pull that piece in slowly,” she said. “Once I have engaged and gotten it away from the capsular crowding, I can go deeper into the third position of the foot pedal, engage more torsional ultrasound energy and disassemble that nuclear piece.”

With dense nuclei, she uses a slightly tighter grid pattern, which creates smaller cubes (Figure 1). “With the numerous femto-fragmented pieces, you often don’t need to engage a lot of phaco energy. Also helpful is customizing the foot pedal to create greater excursion time in foot position 2, which will allow for more controlled aspiration of the pieces and is useful with laser-assisted cataract surgery as well as very soft lenses,” she said.

“When you’re dealing with newer technology, there is a learning curve,” Dr. Yeu said. “Femto phaco has made cataract surgery more interesting, especially when you get to customize your patterns to best benefit patients.”
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CME questions (circle the correct answer)

1. According to Dr. Park, the following drug has been implicated in intraoperative floppy iris syndrome in women:
   a. Simvastatin
   b. Terazosin
   c. Sulfamethoxazole/trimethoprim
   d. Digoxin

2. Venturi systems:
   a. Are compressed air systems
   b. Are not occlusion dependent
   c. Have a rapid rise time
   d. All of the above

3. According to Dr. Cohen, with the peristaltic pump, _______ largely controls distal followability:
   a. Flow
   b. Vacuum
   c. Intraocular pressure
   d. Incision architecture

4. Hyperpulse power modulation delivers:
   a. 50 pulses per second
   b. 80 pulses per second
   c. More than 100 pulses per second
   d. More than 150 pulses per second

5. To hold onto the lens fragment during phaco chopping, Dr. Henderson suggests:
   a. Increasing vacuum
   b. Using a second instrument beneath the phaco tip
   c. Using a different viscoelastic
   d. All of the above

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