

Optimize Your Ride

Why choose between peristaltic and Venturi when dual-pump fluidics allows you to use both to maximum effect?

BY DAVID B. YAN, MD

We cataract surgeons tend to think of ourselves as either Venturi or peristaltic surgeons, advocating our preferred fluidics style much as a driver might argue the benefits of a manual versus automatic transmission on a car. Although both types of pumps have merit, the choice between them was until recently made at the time of equipment acquisition.

A few years ago, dual-pump systems such as the Stellaris PC Vision Enhancement (Bausch + Lomb) and WhiteStar Signature (Abbott Medical Optics) were developed to satisfy different pumping preferences in a multisurgeon environment. Each could be set up with the Venturi pack for the stick-shift drivers and the peristaltic pack for the automatic drivers.

Even the most passionate sports car driver might find him- or herself wishing for an automatic transmission when rush hour traffic is backed up for miles. Automated dual-clutch transmissions now allow drivers to choose between the speed of a manual and the smoothness of an automatic, and this can be done in the phaco suite as well with the WhiteStar Signature.

Phacoemulsification is composed of two discrete tasks, chopping and segment removal. This article explores the different fluidics required of the phaco pump for each step.

CHOPPING

For chopping, the phaco pump keeps the lens stationary at the tip of the phaco needle by generating a pressure differential between the fluid lines and the anterior chamber when the phaco tip is occluded (Figure 1). This is referred to as “holdability.” For this task, a peristaltic pump is superior, primarily because

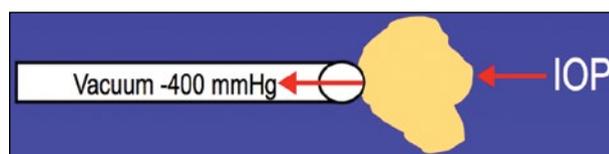


Figure 1. When a piece of nucleus occludes the phaco tip, a pressure differential is generated between the fluid lines and the anterior chamber.

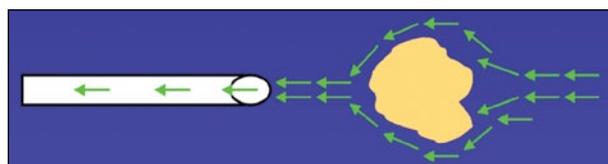


Figure 2. With a Venturi pump and high rate of flow, nuclear fragments will move to the phaco tip, because they get caught in the fluid stream heading into the phaco tip.

it has a built-in pressure transducer that tells the surgeon exactly how much vacuum has been generated at the phaco tip. The peristaltic pump can safely generate much higher vacuum levels (≈ 400 - 500 mm Hg) compared with Venturi systems (≈ 150 - 200 mm Hg with 20-gauge needle tips). In addition, peristaltic pumps can generate this higher vacuum using much lower flow rates (≈ 20 - 30 mL/min) than Venturi systems (≈ 60 - 70 mL/min). Higher vacuum generates stronger holding power, and lower flow provides a more stable purchase of the lens.

It is no surprise that most cataract surgeons have traditionally preferred a peristaltic phaco machine because it is better for chopping. Segment removal will be difficult regardless of the phaco pump if the chopping that preceded it was executed poorly.

SEGMENT REMOVAL

The surgeon wants nuclear segments to constantly move toward the phaco tip instead of remaining stationary. Nuclear fragments move to the phaco tip because they get caught in the fluid stream heading into it (Figure 2). In fluidics, this is referred to as *entrainment*, much like a raft would get swept downstream in a rushing river.

During segment removal, a high and uninterrupted flow rate is ideal to use followability to draw nuclear segments out of the capsular bag, allowing the phaco tip to safely stay at the iris plane.

Venturi pumps are better suited to create the optimal fluidic conditions for high followability with a stable chamber during segment removal. First, they can safely generate much higher flow rates ($\approx 60\text{-}70$ mL/min) than peristaltic pumps ($\approx 30\text{-}44$ mL/min). Second, Venturi pumps require lower vacuum levels ($\approx 150\text{-}200$ mm Hg) than peristaltic systems ($\approx 300\text{-}450$ mm Hg) to generate this flow. Lower vacuum helps prevent line collapse and postocclusion surge, and higher flow rates allow the phaco tip to stay safely central and away from the posterior capsule.

Interestingly, surgeons often think of peristaltic systems as being very safe because of their surge protection features. Automated step-down features are necessary to stop the pump during tip occlusion before the maximum vacuum levels set by the surgeon are exceeded. Quickly stopping the pump at maximum vacuum is much like slamming on the brakes when the traffic light turns red.

Modern Venturi systems feel dramatically more stable than previous generations because of the reduced air volume in the cassette. Older systems were designed with large cassettes so they would not fill up during a case. The Millennium Venturi system (Bausch + Lomb) has a cassette volume of approximately 250 mL, whereas the Stellaris cassette is approximately



Figure 3. The Signature system's Venturi cassette uses a blue light beam to detect fluid levels instantaneously and turn on the venting pump as required.

300 mL. The Venturi cassette on the latter device is much smaller (≈ 65 mL) but never fills, because a second peristaltic venting pump senses the fluid level and automatically empties the cassette to maintain a very small but consistent air volume needed to generate vacuum (Figure 3). With a compressible air volume that is five times smaller, the Signature system is more stable than systems without cassette venting pumps.

The Stellaris uses a flow restrictor (cruise control) in the vacuum lines between the phaco handpiece and the Venturi cassette to help prevent postocclusion surge. When occlusion breaks, cruise control pre-

TABLE. PHACO MODES AND SETTINGS^a

Phaco Step	Pump Type	Aspiration Flow Rate	Vacuum
Chopping	Peristaltic	30 mL/min	450 mm Hg
Segment removal (first two to four pieces)	Venturi	≈ 66 mL/min	200 mm Hg (20-gauge tip) 300 mm Hg (21-gauge tip)
Segment removal (last one to two pieces)	Venturi	≈ 50 mL/min	150 mm Hg (20-gauge tip) 225 mm Hg (21-gauge tip)

^aPeristaltic for chopping and two Venturi submodes for segment removal optimize the balance between speed and safety throughout the procedure.

THE UTILITY OF A VACUUM-BASED PUMP SYSTEM IN COMPLEX CATARACT CASES

BY ROBERT J. WEINSTOCK, MD

When confronted with complex cataract cases, the surgeon must have high confidence in his or her phaco machine and must know how to use it well to be successful. In such cases, precise vacuum/aspiration control can aid the surgeon. I use the Stellaris Vision Enhancement System (Bausch + Lomb) with Digiflow and dual linear vacuum control. These features allow me to be successful in the most challenging of cases.

For example, in patients with intraoperative floppy iris syndrome, precise vacuum control reduces the risk of drawing the iris into the phaco needle. During aspiration, as each piece of lens occludes and then clears the phaco tip, everything behind it is at risk of being incarcerated in the phaco tip. When occlusion breaks, the rotary vane vacuum system in the Stellaris recognizes the change and controls the system's vent, immediately reducing the vacuum level. With other peristaltic-based aspiration systems, I have noticed a slower response when occlusion breaks. These anterior chamber dynamics are also a concern in patients whose chambers are inherently unstable, such as those who have had previous vitrectomies, or chambers that are unusually deep, as is the case in high myopes. Precise and responsive vacuum control is critical, because these chambers can collapse very quickly as occlusion breaks.

The dual linear foot pedal adds another level of surgeon control that is particularly useful in dense cataracts. With the system's foot pedal, there are two vacuum controls: one in the linear foot position 2 and the other engaged by moving the foot pedal to the right in the "yaw" position. During the removal of dense cataracts, robust vacuum is helpful in moving and impaling pieces of nucleus. The foot pedal yaw mode provides an instantaneous boost of vacuum to

remove dense pieces of nucleus with short pulses of phaco energy. Having extra vacuum on demand can significantly reduce my need to use ultrasound power to remove dense particles. Vacuum aspiration is also essential for challenging cortical cleanup, which can be an issue in laser-treated eyes.

Of course, the added benefit of relying more on vacuum than on ultrasound power in dense cataract cases is the reduction of corneal edema the next day. Although dispersive viscoelastics (Viscoat [Alcon] or Endocoat [Abbott Medical Optics]) provide some protection, ultrasonic energy can damage endothelial cells. Particularly in eyes with compromised corneal endothelium, as in Fuchs dystrophy, low phaco energy during cataract surgery can make the difference between a clear cornea and permanent haze. The system provides excellent cutting efficiency with a handpiece that delivers a lower frequency (28.5 kHz) yet a higher stroke length than other machines. Coupling the system's responsive high vacuum settings with pulsed phacoemulsification minimizes the energy introduced into the eye, while not compromising the stability of the chamber or cutting efficiency.

Whether a case is complex or routine, the capabilities of the Stellaris system with high vacuum settings, and the precise control they allow, make it suitable for coaxial and biaxial surgery. I perform a high volume of microincisional cataract surgery with this platform. The fact that it supports combined cataract and vitreoretinal procedures is a further advantage.

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vents a rapid transfer of fluid from the anterior chamber into the vacuum lines. During unoccluded operation, however, a higher cassette vacuum is required to generate a given flow rate compared with systems that do not have a flow restrictor. The higher vacuum in the Stellaris Venturi system improves holdability for chopping, but the unit may not detect occlusion because the platform lacks a pressure transducer in the vacuum lines that is found in peristaltic systems.

Transversal phacoemulsification such as the Ellips FX (Abbott Medical Optics) technology can work synergistically with the excellent fluidic characteristics of

the Venturi pump to keep the fragments moving and prevent the "lollipop" tip occlusion that can otherwise reduce the speed and efficiency of segment removal (Figure 4).

PUTTING IT ALL TOGETHER: COMPARING FLUIDICS

The functional differences between peristaltic and Venturi pumps can perhaps be best illustrated by plotting their fluidic properties on a flow-vacuum graph (Figure 5).

There is a linear relationship between flow rate and

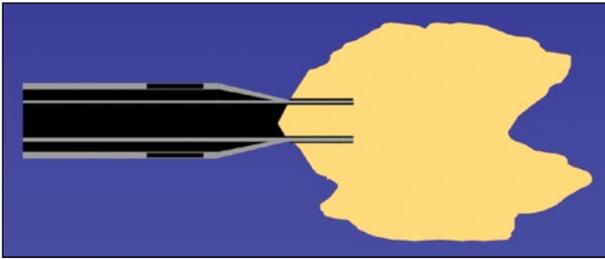


Figure 4. Transversal phacoemulsification and Venturi fluidics help to keep nuclear fragments moving and prevent the “lollipop” tip occlusion.

vacuum for Venturi pumps: doubling the vacuum will double the flow rate as well. The Venturi pump creates a high flow/low vacuum condition in the unoccluded state ideal for segment removal with good followability.

For peristaltic pumps, the flow rate is preset and will remain relatively constant as long as the phaco tip is unoccluded. Nuclear occlusion of the phaco tip increases flow resistance, and vacuum rises accordingly. At some vacuum level below the preset maximum (300 mm Hg in Figure 5), the peristaltic pump will begin to decelerate, and the flow rate will decrease. As the vacuum reaches the preset maximum allowed (450 mm Hg in the illustrative example), the pump stops to prevent further buildup of vacuum. Nuclear material is usually occluding the phaco tip during chopping, so the peristaltic pump will operate in a high-vacuum, low-flow condition ideal for good holdability.

THE RIGHT TOOL FOR EACH TASK

Performing the entire phaco procedure with one type of pump will compromise fluidics. Chopping with a Venturi pump will result in undesirably high flow rates to generate the high vacuum required for holdability. It would be a bit like towing a boat with a Porsche or turbocharging a minivan for a day at the racetrack; the system is being asked to do something at which it does not excel.

The WhiteStar Signature has solved the dilemma of compromised fluidics in single-pump systems by allowing surgeons to switch on the fly between dual pumps with Fusion Fluidics (Abbott Medical Optics). My preferred method of phaco surgery is to begin with peristaltic pumping and chop the nucleus into two to six pieces, depending on its density. In this chopping mode, the flow rate is set relatively low (20-30 mL/min) and vacuum relatively high (≈ 450 mm Hg; Table). Next, I switch to Venturi to

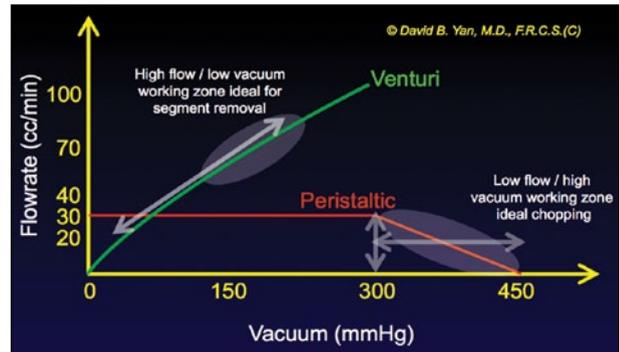


Figure 5. The functional differences in fluidic properties of peristaltic and Venturi pumps. The flow rate/vacuum operating characteristics of the Venturi pump are illustrated with the green line, and the characteristics of the peristaltic pump are illustrated with the red line.

remove the segments at approximately 200 mm Hg for 20-gauge phaco tips and about 300 mm Hg for 21-gauge tips. For the last few segments, I may switch to a slow 150 mm Hg submode, because the remaining segments are already highly mobile, and there is a greater risk of capsular rupture.

CONCLUSION

Using a peristaltic pump for chopping and Venturi for segment removal is the optimal fluidic setup for most cataracts, but it may be easier to use just one pump for some cases. In eyes with very soft lenses, I may rely on Venturi fluidics for the entire case using a phacoaspiration technique. I may depend on peristaltic fluidics in cases of intraoperative floppy iris syndrome and reduce the flow rate to about 20 mL/min to minimize the risk of iris incarceration.

Utilizing the strengths of two pumps—peristaltic for chopping and Venturi for segment removal—offers surgeons the rare opportunity to improve both safety and efficiency in cataract surgery. Now, surgeons can finally get sports car performance but also minivan safety and utility in a single phaco machine. ■

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