



Supplement  
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# Phaco Basics and Beyond



**ESCRS**  
Education Forum



# Today's Phaco: A Look into the ESCRS Clinical Trends Survey

Paul Rosen, BSc, FRCS, FRCOphth

The annual Clinical Trends Survey of European Society of Cataract & Refractive Surgeons (ESCRS) suggests that in 2017, the confidence level and know-how with respect to phacoemulsification performance was high and on an upward trajectory. Close to 1,900 ESCRS delegates responded to the survey. Almost one-quarter of the participants perform more than 600 cataracts per year, and an additional 15% perform 400-to-600 cataract surgeries annually.

During phacoemulsification, divide-and-conquer and stop-and-chop are the favoured methods of breaking up the nucleus among responders, at 32% and 31% respectively (Figure 1). Vertical chop and horizontal chop are less popular, with 21% and 14% acknowledging that they preferred those methods of breaking up the nucleus.

In response to the question "What is your current level of confidence to optimise your phaco machine settings to manage standard cataract cases?" 86% say they are either confident, very confident or extremely confident, leaving only 14% questioning their capabilities - 10% say they are somewhat confident and 4% report being not confident at all.

## Dense and Complicated Cataracts

Responders were slightly less secure in their confidence level about managing dense cataracts, with 18% being somewhat or not confident; but overall the vast majority were comfortable optimising phaco to treat dense cataracts, with 61% being very and extremely confident.

The confidence level further shrank in response to a query about their confidence level managing phaco settings in complicated cases such as those with small pupils, soft lenses, intraoperative floppy iris syndrome (IFIS) and weak zonules, with 51% reporting being very confident or extremely confident in their understanding (Figure 2).

## Phaco Setting Security

Careful analysis of responses and associated attitudes suggest that more than half of the survey responders are not sufficiently secure in optimising their phaco settings - particularly in dense cataracts and complicated cases. The ESCRS Education Forum aims to gather and evaluate data to identify where education is needed most for its members.



**The goal of the Clinical Trends Survey is to use the data generated from the annual survey of ESCRS members to address obstacles to improving clinical outcomes and practice patterns**

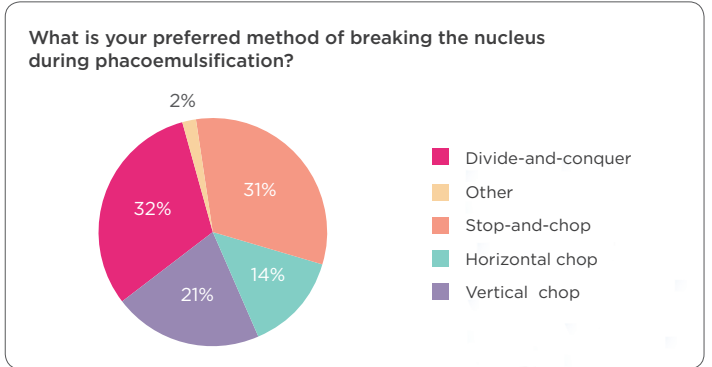


Figure 1. Divide-and-conquer and stop-and-chop were most preferred methods of breaking the nucleus during phacoemulsification

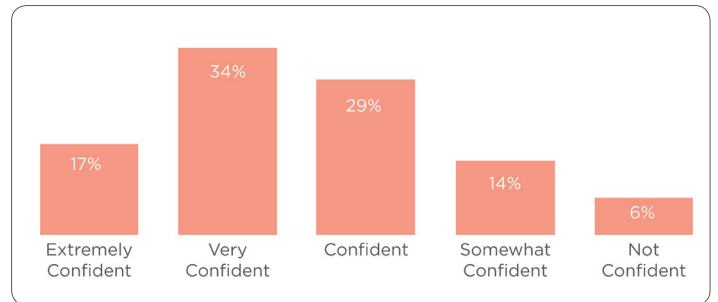


Figure 2. According to the 2017 ESCRS Clinical Trends Survey, 51% of respondents are not very or extremely confident in optimising phaco machine settings for common complicated cataract cases

The goal of the Clinical Trends Survey is to use the data generated from the annual survey to address obstacles to improving clinical outcomes and practice patterns.

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# Phaco Power Modulation Through the Years

Richard Packard MD, DO, FRCS, FRCOphth

**P**hacoemulsification power modulation reduces the amount of ultrasound (US) energy in the eye during cataract surgery, which engenders less endothelial cell damage due to the release of free radicals. A look back at early phaco reminds us that initially we only had one pre-set power – panel power. This means that once the foot pedal was in foot position 3, the machine was at the highest level that the surgeon had chosen. In practice, because it wasn't very efficient, we tended to use 100% power, which meant a 100% duty cycle. Over the ensuing decades, kinder, gentler ways to break up and remove the nucleus were introduced.

## Power Modulation

In the early 1980s, linear power arrived, ushering in major advances because with it came the ability to control power via foot pedal (Figure 3). Pulsing and burst arrived a decade later. The latter meant that the frequency gradually increased for each pulse until we got to continuous phaco power – the power was not linear and was generally set at about 30%.

Micropulse and microburst are the modern modulated power modes that grew out of the earlier modes. In 2001, the Sovereign Whitestar (Allergan, now Johnson & Johnson Vision) gave us micropulsing. This was noteworthy because not only could we vary the length of the US pulse, but we could also vary the space in between pulses. This led to us trying various ratios of millisecond power to millisecond break, until we arrived upon what worked best. With the Infiniti (Alcon), we got microburst, which is a combination of micropulse and burst – effectively burst with micropulses, but also linear in power delivery. As we have seen, micropulse and microburst consist of an US burst and then a rest and this combination creates the total pulse. This mode produces a reduced repulsive force at the phaco tip, which is particularly important with hard cataracts.

## Longitudinal vs Torsional

All manufacturers of phaco machines have attempted in different ways to maximise efficiency of energy delivery and minimise energy dispersed into the eye by power modulation. For example, in 2006, Alcon introduced a different method of moving the phaco needle known as torsional or OZil. It was introduced on the Infiniti and is also found on the Centurion.

With torsional, instead of the backwards-and-forwards movement that is associated with longitudinal, we get side-to-side movement. This makes for more efficient cutting because we get cutting every time the tip is moving, unlike longitudinal phaco which only cuts when it moves forward.

OZil works at 32kHz, which gives a lower heat signature than longitudinal phaco. Traditional phaco works like a jackhammer, whereas the torsional tip utilises a shaving motion that breaks the nucleus into an emulsate for aspiration. I use continuous OZil for sculpting and chopping and microburst for segment removal, 35msec on and 40msec off.

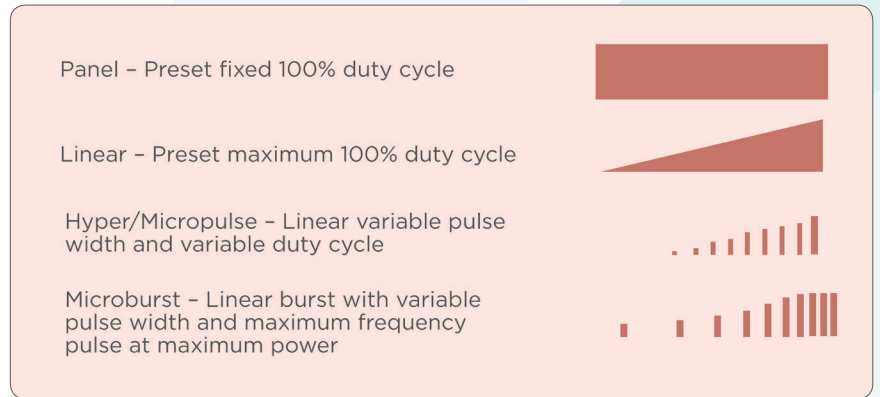


Figure 3. Traditional and modern power modes include panel, linear, micropulse and microburst

## Intelligent Phaco

Initially, there was an issue with OZil where sometimes with harder cataracts a fragment could clog the tip – particularly with flared tips. To remedy this, Intelligent Phaco (IP) was introduced on the Infiniti, and it is still available on the Centurion. With IP, the machine gives a short pulse of longitudinal energy to push away the remaining nuclear fragment and then returns to emulsifying at a preset vacuum level.

## Elliptical Movements

No discussion of phaco modulation would be complete without a look at Johnson & Johnson Vision's Signature Pro with its transversal Ellips FX US, or the customisable Bausch + Lomb Stellaris Elite. The Ellips FX mode provides a double movement: back and forth and side to side. Although this is designed to work with a straight needle, I prefer it with a Kelman-style tip because I think this combination makes it more efficient. The Signature Pro functions at 38kHz and enables the user to customise settings. I use a sculpt setting with an Ellips power setting of 40% with 4ms on and 8ms off in a linear manner. It is possible to have different settings for unoccluded and occluded mode, which is particularly useful for harder nuclei when removing chopped or cracked segments.

The Stellaris uses only longitudinal phaco, but it has multiple modulations of micropulsing. The frequency of this machine is 28.5kHz, so it has a lower heat signature, and you can increase efficiency by using a waveform shaping of the pulses. One of the things that Bausch + Lomb did when they moved from the Millennium to the Stellaris was to increase the stroke length. This effectively means that you can reduce the power setting by 25% because stroke length is determined by the power used.

The custom control software allows the user to customise the shape of the pulses. With this system, I use a 50% duty cycle with 20% pulsed at 6ms.

In summary, phaco power modulation reduces the amount of energy in the eye during cataract surgery, and this in turn reduces free radical release, which results in



less endothelial cell damage. It can be done with linear control, with micropulsing, with microbursts and by changing pulse modes between unoccluded and occluded. You can also use alternative phaco tip movements, such as torsional and transversal.

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## Phaco Fluidics: The Ins and Outs of Inflow and Outflow

*Paul Rosen, BSc, FRCS, FRCOphth*

**P**hacoemulsification is all about inflow and outflow. The inflow of fluid comes from one source – the bottle of balanced salt solution – while the outflow of fluid comes from two sources: suction via the phaco needle and leakage from around the incisions.

As we know, inflow can occur via the traditional method of using gravity, or we can instead use active methods of forced infusion with a pressurised bottle or a compressible bag. Outflow, on the other hand, is all about aspiration; removing material from the eye, as well as leakage.

Ultimately, the goal is to maintain a stable anterior chamber of comfortable depth, to avoid surge, to minimise damage to the cornea with free radicals and to minimise heat production in the wound. However, most surgeons don't adequately match the size of their instruments to the size of their incisions, and this can have a profound effect on the way the phaco machine works.

### Anterior Chamber Stability

Active irrigation can make things easier. When you aspirate with your phaco instrument, you aspirate volume from the anterior chamber, and it must be replenished by your irrigation. The speed with which it is replenished is dependent on your intraocular pressure (IOP) or the bottle height of your phaco machine. At full aspiration rates, your minimum bottle height is set by the phaco machine because when you aspirate fluid from the anterior chamber it has to be replenished at sufficient rates so that your anterior chamber doesn't collapse. However, if you stop aspirating, you will still have that same bottle height and a very high IOP.

With active fluidics, it's much more interactive; the irrigation flow is dependent on how much volume you take out of the anterior chamber. Your IOP will be much more stable, so you can use lower IOPs throughout surgery, and this is associated with better outcomes.

Active fluidics compensate for all the outflow with inflow and maintain a stable anterior chamber. Ultimately, we must balance inflow and outflow.

### Peristaltic vs Venturi Pumps

So much is dependent on the type of pump used (Figure 4). With the flow-based Peristaltic pump, vacuum is created only after you have full occlusion. Although there is flow coming towards the phaco tip, this is generated by the pump and the speed at which it is turning. You will not get any vacuum with a Peristaltic pump until you have occlusion. You can also increase the flow by speeding up the pump once you get occlusion to get your preset vacuum level. As you approach your chosen vacuum level, the pump slows down.

Initially, most phaco machines were Peristaltic, so we are familiar with and comfortable with the way these systems work. Venturi vacuum-based phaco systems are very different, requiring a different technique, but equally effective. Vacuum and flow are actually the same thing on these machines – they cannot be separated, but you get instant vacuum, so you don't need occlusion. This means the nuclear fragments will be drawn toward you during the entire process, which makes for fast, efficient surgery. Many experienced surgeons prefer to use this approach.

There are certain advantages in, for example, doing irrigation/aspiration on a Venturi system. However, modern machines are evolving to the point where even on a Peristaltic machine you can now have linear flow and linear vacuum, which puts it much closer to a Venturi machine.

Many surgeons consider the Peristaltic safer; but the evolution of phaco pump technology has made both types similar in safety and efficiency. Some systems let us combine the benefits of each, and when that is available it makes sense to take advantage of that.



**The goal is to maintain a stable anterior chamber of comfortable depth, to avoid surge, to minimise damage to the cornea with free radicals and to minimise heat production in the wound**

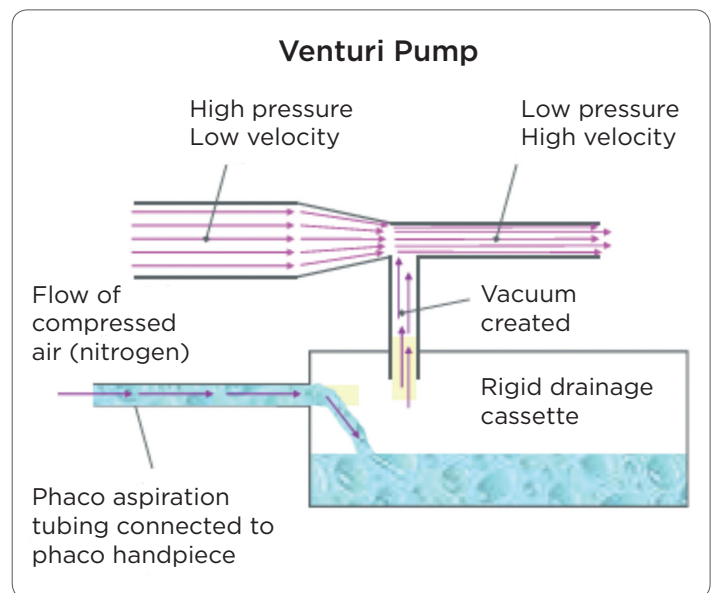
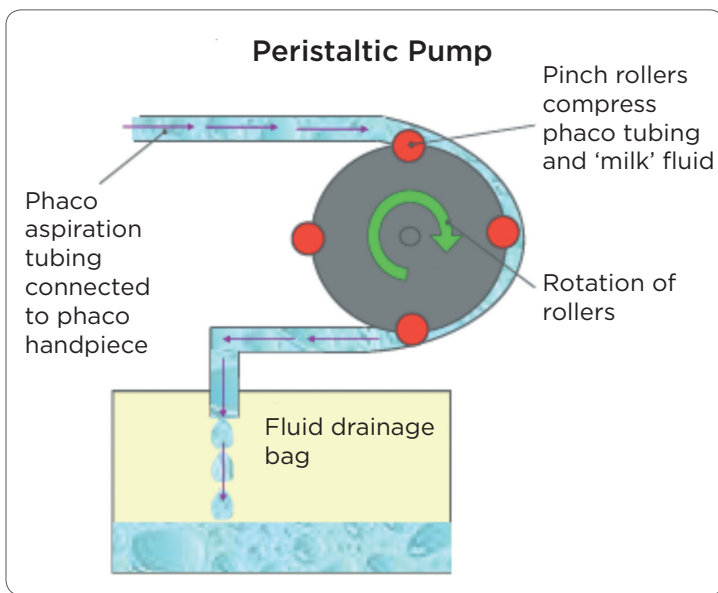


Figure 4. Peristaltic vs Venturi pumps

Most of the Venturi machines have a dual-linear foot pedal. This makes it possible to cut in ultrasound just by moving your foot to the side at any point in the cycle. This is a major advantage and provides considerably more control with a Venturi system than was possible prior to this advance.

### Post-Occlusion Surge

Post-occlusion surge, which is caused when there is an occlusion break and fluid continues to be drawn out of the

eye, is another important concern. This is much less of an issue with modern machines than it once was, because we now have active fluidics pushing fluid into the eye to mitigate against this. A Peristaltic system maintains the vacuum at full occlusion for a set amount of time. It then anticipates that you are not going to need full occlusion for such a long time, so it drops it back down before you get the occlusion break – all in an effort to minimise surge.



## Setting Parameters for Phaco Fluidics

Filomena Ribeiro MD, PhD, FEBO

The Peristaltic pump and the Venturi pump are distinctly different types of phacoemulsification technology, and each system has unique advantages and disadvantages. Sometimes a combination of Venturi and Peristaltic technologies can be employed for the ideal assistance when setting parameters for different steps of the cataract surgery, in specific cases. Optimising machine settings for different objectives is an important factor in successful cataract surgery. Surgeons must understand the principles to improve power and fluidics to be efficient, and to maintain a stable anterior chamber and less intraocular trauma.

With the Peristaltic pump, we must set flow and vacuum limits. Flow is constant until occlusion, and on complete occlusion the vacuum is at its highest level. The advantage for this pump type is that vacuum-building is safer; however, it may require more time and manipulation to capture nuclear fragments.

The advantages of the Venturi pump are that it is able to create the preset vacuum level without occlusion of the phaco needle tip; there is only one variable to change; it has a rapid rise time; and we can keep the phaco tip in the centre and expect the nuclear pieces to follow. Its only disadvantage is that flow is dependent on the vacuum level.

A Peristaltic pump requires tip occlusion for vacuum to be active, and as a result it does not draw material as easily and quickly to the tip as a Venturi pump does. With the Peristaltic pump, occlusion automatically lowers the vacuum for safety; whereas, with the Venturi pump you can have vacuum without occluding the tip.

Refinement of these systems has resulted in there no longer being a dramatic difference in safety between Venturi and Peristaltic systems. However, the increased efficiency of Venturi systems gives them the advantage when it comes to overall phacoemulsification performance.

### Holdability and Followability

When addressing the safety vs efficiency factors of Venturi and Peristaltic systems, “holdability” and “followability” are two key concepts to consider (Figure 5). Holdability, which is associated with the Peristaltic pump, refers to how the pump holds large lens fragments at the tip and enhances control. However, when occlusion breaks, there can be a significant surge, and this is the primary problem of the Peristaltic system. While it is safer than it once was, this is still a problem.

Followability, which is associated with the Venturi pump, equates to low vacuum with high flow. This means the

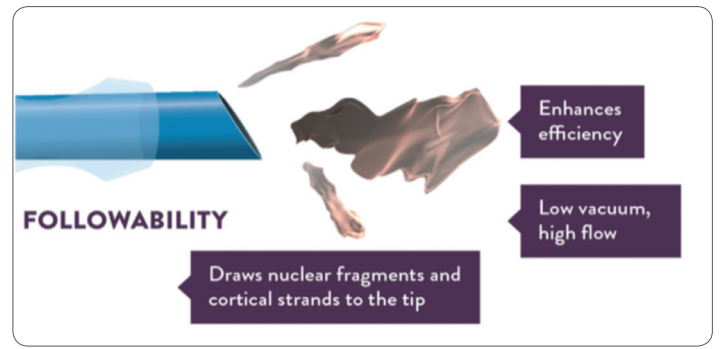
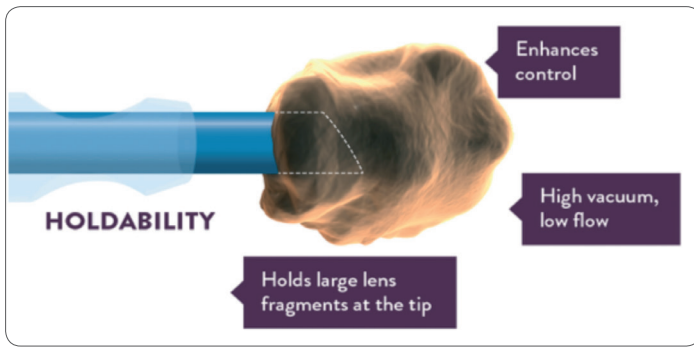


Figure 5. Holdability and Followability are key concepts when considering Venturi and Peristaltic fluidics

vacuum exists without occlusion, and we are always controlling the vacuum. Of course, it is important to recognise that steadily applied vacuum can put the iris and capsular bag at risk. Followability draws nuclear fragments and cortical strands to the tip, enhances efficiency and enables low vacuum and high flow.

### Best of Both

When the advantages of followability and holdability are combined, we have the best of both worlds. This is what we see with the dual-pump systems, such as the Whitestar Signature phaco system. On-Demand Fluidics enable the surgeon to have it both ways: the Peristaltic pump affords control when needed, and the Venturi pump, provides for the option of efficient extraction, excellent chamber stability, and ultrasound efficiency.

As no two cataract surgeries are identical, you should not limit your options. More choices and extra flexibility are always preferable during surgery. By using the strong point of each pump, with easy transition, we are able to be safer and more efficient.

We can use one type of pump if its capabilities will suffice for the type of cataract we are removing. However, we can also easily transition between Peristaltic and Venturi pumps if necessary (Figure 6). For instance, use Peristaltic with holdability for chopping and Venturi with enhanced followability to remove pieces of the nucleus.

Use the Venturi irrigation/aspiration to remove the cortex. With the vacuum on all the time with the Venturi system, cortical removal is extremely efficient. The fusion of different technologies into one system is purported to offer flexibility for the surgeon and may even improve efficiency.

### Case Examples

In the case of a moderate cataract, for instance, where we are using only Venturi, we can do the crack easily maintaining the tip in the centre of the anterior chamber where it is safer to do all the surgery. With this kind of pump, we can use lower vacuum levels and it makes it easy to drive the fragments to the tip without approaching the periphery for the fragments. One thing to point out is that it is important always to have a good balance between inflow and outflow, which means good anterior chamber stability, and a successfully created incision.

In another example, the Venturi pump is quite effective in the case of a white cataract. Intumescent cataracts usually have a high pressure intracapsular bag, so we first perform a small capsular puncture to aspirate all the liquified cortex. After that, we can more safely start to perform the capsulorrhexis. The hydrodissection must be soft with this type of cataract. The Venturi pump can be very useful in these cases thanks to the followability.

The case of a floppy iris - with the triad iris billowing and floppiness, iris prolapse and progressive miosis - is an excellent vehicle to illustrate how important holdability and followability are to a safe and efficient outcome. In this case, use a Venturi pump system, work in the centre of the anterior chamber, and focus on using followability.

In conclusion, Venturi and Peristaltic fluidics, and holdability and followability each play an important role in phaco.

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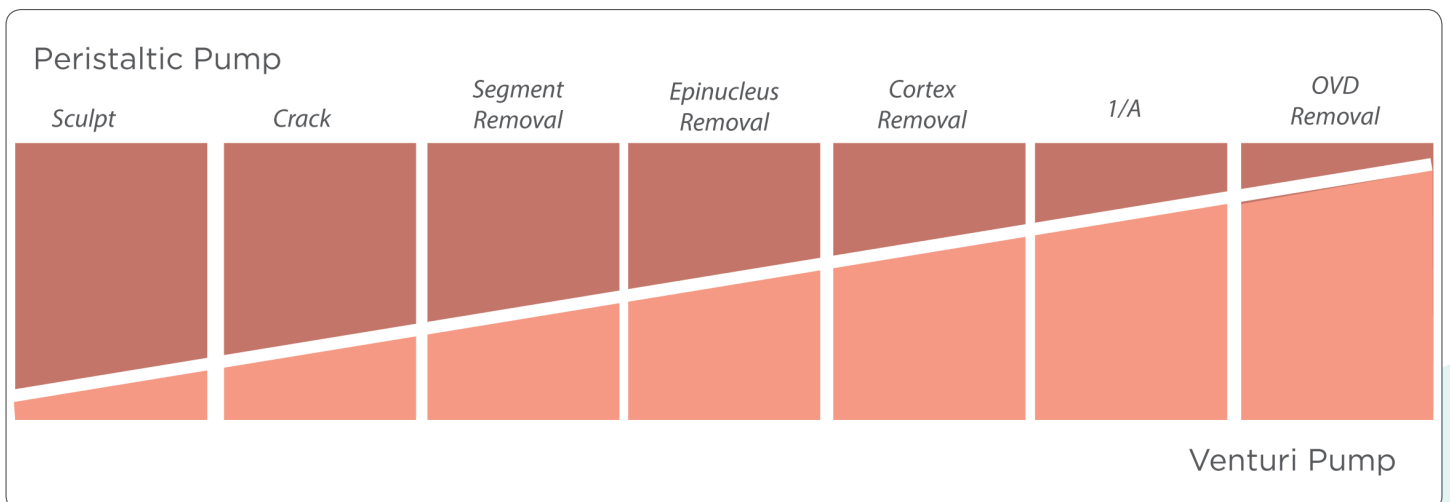


Figure 6. Transition between holdability and followability to increase overall performance



# Matching Phaco Machine Settings to Specific Cataracts

Nic J. Reus, MD, PhD

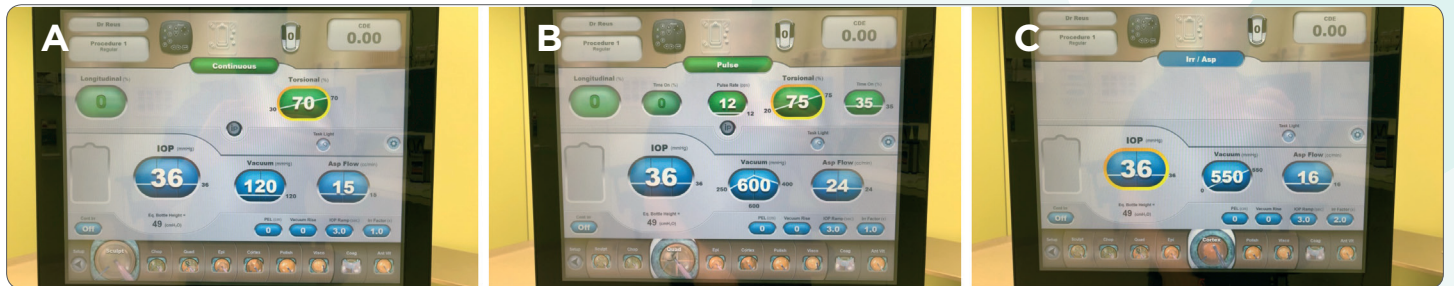


Figure 7. Settings for standard cataract cases at the beginning of a standard case (A) when I begin quadrant removal (B) and during cortex removal (C)

**P**eristaltic pumps, in general, and the Centurion phacoemulsification system, in particular, allow for efficient, safe removal of the lens in almost all cases with standard settings. Low aspiration flow rates, low risk of intraoperative floppy iris syndrome (IFIS), low intraocular pressures (IOP) and high vacuum combine to make it possible to perform efficient phaco with these standard settings. However, settings can naturally be optimised to conquer even the most difficult cases safely.

## Stable Anterior Chamber

With its Intrepid Balanced tip and OZil torsional technology, the Centurion is known for efficient phacoemulsification. It facilitates a stable anterior chamber due to active fluidics. It compresses the bag with balanced salt solution (BSS), and the more you remove fluid from the anterior chamber, the more it compresses the bag refilling the volume that was removed. This dynamic allows the machine to have low aspiration flow rates, with a low risk of IFIS. But even with the low aspiration flow rates and low intraocular pressures, you can use a high vacuum.

## Standard Cases

In about 90% of my cases, I do not change any settings. My typical settings are the following: IOP of 36mmHg at sculpt, which maintains pressure in the eye; vacuum of 120mmHg, which allows good removal of viscoelastic to avoid occlusion of the phaco tip and avoid wound burn during sculpting; and flow rate is set relatively low at 15mm/min (Figure 7A). My rationale for that is that if I increase it, I might risk attracting the lens itself, and instead of sculpting a groove I might inadvertently take out the lens. My rise time is zero, which is the standard rise time of the instrument.

When I begin quadrant removal, my IOP is maintained, but my vacuum changes (Figure 7B). When I start in foot pedal position 2, I begin at a vacuum of 250mmHg. When I go up to foot pedal position 3, it reaches a vacuum of 600mmHg. When I push down on it, it lowers the maximum amount of vacuum that can build up. It has an aspiration flow rate of 24mm/min, which allows for good followability. For cortex removal, my IOP settings remain at 36mmHg, and I've got a linear vacuum going from zero to 550mmHg, with a fixed flow rate of 16mm/min (Figure 7C).

An example of a standard case demonstrates that I employ a nucleofractis or divide-and-conquer technique. I first make a groove; then I split the lens into four fragments. I use the standard IOP of 36mmHg and maintain a stable anterior

chamber with a vacuum of 120mmHg. Next, I move on to quadrant removal. I like to slice the nucleus, and this works well with the Centurion because with OZil technology, the tip oscillates, and you shave your nucleus. For that to work it's important that the nucleus be able to rotate around the tip. If it doesn't rotate around the tip, you will get an occlusion. The smaller the fragments, the more efficient the phacoemulsification will be.

If there is epinucleus, you must remove it. When you remove the cortex, the epinucleus will follow because it is attached to the cortex; the result is a clear lens bag. For cortex removal, I use bimanual irrigation and aspiration. The Centurion has a polymer I&A tip that is soft and can be used to polish the posterior capsule safely. Finally, I put the lens in and remove the viscoelastic. I use a fixed flow rate of 22mmHg and a fixed vacuum of 500mmHg for efficient viscoelastic removal.

## Dense Cataracts

I use the same settings for a dense brunescant cataract as I use for a standard cataract, except that I increase the maximum amplitude of phaco tip oscillation to engage more phaco power to emulsify the lens. In these cases, I like to use a chopping technique, which I can do easily with OZil technology. I use longitudinal phaco power to dig the phaco tip into the nucleus and keep holding power there with a maximum vacuum of 500mmHg and a fixed flow rate of 24mm/min. These are very efficient settings with an IOP of just 36mmHg; I have almost no surge with this instrument.

## Intraoperative Floppy Iris Syndrome

In the case of IFIS, if the pupil is not optimally dilated with Mydrasert I instil Mydrane, which is a combination of tropicamide, phenylephrine and lidocaine, to increase the pupil size. In a case like this, I often adjust my flow rate down to 14mm/min. It's a bit slower than with a higher flow rate, but it is still a very efficient way to emulsify the lens fragments. The anterior chamber remains stable, and the procedure is quite safe under these parameters.

In conclusion, Peristaltic pumps allow efficient, safe removal of the lens with standard settings in almost all cases. Setting adjustments are an option that can add additional customisation for specific cases.

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