Modulating ultrasound energy reduces adverse effects and increases the efficacy of fluidics.

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Today, the aim of cataract surgery is not only to restore vision by removing and replacing the cataractous lens, but also to simultaneously provide instant and high-quality visual rehabilitation. Achieving a clear cornea immediately after surgery is the first step in this endeavor. One of the most important barriers to achieving clear corneas and sharp vision immediately after cataract surgery is damage from ultrasound energy induced during the procedure. The advent of ultrasound power modulation has dramatically increased the efficiency of ultrasound energy and minimized heat production, thereby decreasing the risk of thermal injury that contributes to endothelial cell loss and corneal edema.1,2

In addition to longitudinal ultrasound, which for many years was the only ultrasound modality available, there are now torsional and elliptical ultrasound modalities. Although these modes have advantages in terms of reducing chatter, increasing efficiency, and reducing the amount of energy used in the eye,3 the use of power modulation is as important with these modalities as with traditional longitudinal ultrasound.

UNDERSTANDING POWER MODULATIONS

Traditional longitudinal ultrasound, when first introduced in phacoemulsification, was employed only in the continuous mode. As the name implies, this mode provides continuous delivery of ultrasound energy without any pause time whenever the surgeon is in footpedal position 3. The delivery of power is controlled linearly using the footpedal, and the maximum power is preset by the surgeon. As the footpedal is depressed, the power rises from 0% to the preset maximum power (up to 100%).

The concept of interrupted energy came first with the Whitestar (now Abbott Medical Optics), when the technology’s pulse mode for ultrasound energy delivery was introduced. This was done with the primary intention of reducing thermal damage to the eye and, as an additional effect, making ultrasound energy more efficient. Pulse mode is a power modulation option that features alternating periods of phaco-on and phaco-off time. Each pulse of ultrasound energy is followed by an equal amount of pause time. The summation of phaco-on and phaco-off time is called one cycle or pulse interval. A duty cycle is defined as the ratio of the on time to the total cycle time in the form of a percentage. With the traditional pulse mode, the duty cycle is fixed at 50%—that is, in any given pulse, the phaco-on time is 50% and phaco-off time is 50%. The surgeon can control only the number of pulses per second. For example, if the surgeon has set 10 pulses per second, the cycle time (ie, total duration) of each pulse is 10 ms. Within each pulse, 5 ms is on time and 5 ms is off time. Here again, as in continuous mode, the power is controlled linearly with the footpedal (Figure 1).

Following the introduction of the interrupted energy concept, further modifications were introduced. Hyperpulse mode enables the duty cycle to be changed and allows a larger number of pulses per second, meaning the surgeon can choose to have 10 pulses per second and designate the phaco-on time. The phaco-off time is automatically set by the software. The amplitude of power is controlled with the footpedal, depending on the preset power.

Burst mode is another variation of ultrasound power modulation with which the time of the ultrasound delivery (ie, burst length) and the frequency of bursts can be controlled. The burst length is fixed on the machine. Thereafter, the surgeon fixes the minimum and maximum
numbers of bursts. As the footpedal is depressed in foot position 3, the burst length remains the same and the frequency of bursts increases to a preset maximum. At the furthest depression of foot position 3, almost-continuous energy delivery is approached (Figure 2).

WHY ULTRASOUND POWER MODULATION?

There are two major drawbacks with the use of continuous ultrasound energy: (1) thermal injury and (2) ineffective fluidics.

Thermal injury and ultrasound energy. When the phaco needle moves continuously, whether to and fro in longitudinal ultrasound or oscillating in torsional, there is generation of heat, which raises the temperature at the incision and inside the eye. Although irrigation fluid in the sleeve protects the incision from thermal injury, wound-site thermal injury is the most common side effect of using any form of ultrasound (longitudinal, torsional, or elliptical) at high preset powers in continuous mode. There is a direct correlation between how much power is used—and, more important, how it is used—and wound-site thermal injury. Clinically apparent wound-site thermal injury is easily recognized by the surgeon. Even more commonly seen with continuous delivery of ultrasound energy is the occurrence of subclinical collagen damage at the incision. Collagen damage and ensuing shrinkage can not only adversely affect the self-sealing nature of the incision but also be a risk factor for postoperative endophthalmitis. It can also induce astigmatism, which could mar the patient’s unaided visual performance following an otherwise uneventful surgery.

In the anterior chamber, large amounts of energy, particularly when delivered continuously close to the corneal endothelium, is a risk factor for corneal edema and endothelial cell damage.1,2 On the other hand, any form of interrupted energy allows the phaco needle to cool during periods of phaco-off. This helps to reduce thermal damage to the incision and the endothelial cells.

Enhancing efficiency with interrupted energy. When continuous energy is used, particularly with longitudinal ultrasound, the constant back-and-forth movement of the phaco tip causes repulsion of nuclear fragments. This leads to chatter of the nuclear material and makes emulsification less efficient. In order to increase efficiency, the surgeon must use higher aspiration flow rates and, consequently, greater bottle heights to increase followability of the material.

When pulse or burst mode is used, once the energy is delivered, the phaco-off time allows the aspiration flow to bring material to the phaco tip, thereby enhancing followability. Thus, even with a modest aspiration flow rate and bottle height, the same vacuum level becomes more efficient. Therefore, in effect, the surgeon can work with lower aspiration flow rates and bottle heights and achieve the same efficiency in surgery.

It has been reported that use of lower aspiration parameters not only leads to better corneal clarity but also reduces the absolute level of intraocular pressure and its fluctuations within the eye.6 Further, a big advantage of using a modest aspiration flow rate and bottle height is that the surgeon can confidently emulsify nuclear fragments at a posterior plane away from the corneal endothelium until the end of the case. As a result, mechanical impact of the nuclear fragments and fluid turbulence damage to the corneal endothelium are avoided. Also, because the energy is delivered further from the corneal endothelium, the ultrasound energy will have less adverse impact on the corneal endothelium.

In this regard, I find torsional ultrasound more efficient than longitudinal, primarily because the side-to-side oscillatory movement of the phaco tip causes no repulsion of nuclear material. This not only reduces energy expenditure in the eye but also creates harmony between the aspiration on one hand, which is trying to attract the nuclear material, and energy on the other, which is emulsifying the material presented to the tip. As a result, I am able to emulsify

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TAKE-HOME MESSAGE

- The concept of interrupted ultrasound energy was introduced to reduce thermal damage to the eye and make ultrasound energy more efficient.
- Drawbacks of continuous ultrasound energy use include thermal injury and ineffective fluidics.
- Modulating ultrasound energy helps reduce the adverse impact of ultrasound energy within the eye and makes the fluidics more effective, allowing posterior plane emulsification with modest aspiration parameters and promoting better outcomes.
the hardest of cataracts using modest aspiration flow rates of 20 to 25 cc/min and bottle heights of 80 to 90 cm with appropriate ultrasound and vacuum. Nonetheless, even with torsional ultrasound, I have found that using burst mode further enhances efficiency and reduces thermal effects.

**COMBINATION OF LONGITUDINAL AND TORSIONAL ULTRASOUND**

The Ozil Intelligent Phaco (Ozil IP) software modulation, available with the Infiniti Vision System and Centurion Vision System (both by Alcon), is a combination of torsional ultrasound with a small burst of longitudinal ultrasound delivered intermittently, which helps to reposition nuclear material and enhances the efficiency of the procedure. The IP software senses any rise in vacuum and responds by emitting short pulses of longitudinal ultrasonic energy through the Ozil handpiece to briefly repel the material from the tip and give the tip the space it needs to continue shearing. The surgeon can set the IP software to respond at a predetermined vacuum level.

**SUMMARY**

Ultrasound energy modulation settings can help the surgeon not only to reduce the adverse impact of ultrasound energy within the eye but also to make the fluidics more effective, thereby allowing posterior plane emulsification with modest aspiration parameters and improving the likelihood of excellent postoperative outcomes.

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