Basic Education Phaco Course

10 June 2017

14:15-15:45hrs

Room 112

HAND-OUTS
Basics Fluidics & Ultrasound

The key point in Fluid Dynamics during phacoemulsification surgery is that the fluid going into the eye should always exceed the amount of fluid going out of the eye at all times. If not, the anterior chamber shallows and the posterior capsule will move upward and potentially come into contact with the phacotip, which can result in a posterior capsule rupture.

The Inflow is determined by the irrigation flow only; The hydrostatic pressure of the water column in the irrigation line until the level of the drip chamber underneath the infusion bottle, is expressed in centimeters (bottle height). The resistance in the entire irrigation line including the narrow space between the sleeve and the phacotip, determines the final irrigation flow: irrigation pressure / irrigation resistance.

When the phacotip is completely occluded and no leak flow occurs through any of the incisions, one must be aware of the actual intraocular pressure. The entire fluid (water) column of the irrigation line presses in the eye. For instance a bottle height of 75cm H2O translates into 750mm H2O, and divided by the relative weight of Mercury of 13.6 results in an intraocular pressure of approximately 55mm Hg. Extreme bottle heights of 150 cm are used by some surgeons, which results in 110mm Hg pressure when the tip is occluded! (Fig.1) One should be extremely cautious about utilizing bottle heights exceeding 100cm which causes pressure spikes of more than 73mm Hg.

![Bottle Height](image)

Irrigation pressure is either passive with a bottle hanging above the level of the eye as described above, or is active by a pressurized system, which is not discussed in this chapter. With an active pressure system, the required pressure can be set on the machine in mm Hg.

Before discussing outflow, we have to understand the different pump systems of existing phaco machines:

- Peristaltic pump systems
- Venturi pump systems

Peristaltic pumps consists of rollers which pushes fluid through a flexible aspiration tubing. The aspiration flow increases with increasing speed of the rollers. (Fig. 2)

Venturi pumps create a vacuum in a rigid cassette by forcing gas through a pipe, connected to the cassette. With more gas force blown through the pipe, higher vacuum is created in the cassette, which in turn attracts more fluid from the aspiration line. (Fig. 3)
The main difference between the two systems is that in Venturi pump systems, the vacuum and aspiration flow are directly linked to each other. One cannot set a high vacuum and a low flow. With a peristaltic pump, vacuum and aspiration flow can be controlled independently. (Fig. 4)

Outflow of the eye during phaco surgery is more complex and consists of the following:

- Aspiration Flow
- Leak Flow
- Surge Flow

As a cataract surgery specialist, I have a very specific preference for peristaltic pump systems. The ability to control vacuum and flow separately is essential for managing challenging cases for me. I am discussing fluidic dynamics in the next paragraph in the peristaltic machine.

Aspiration Flow:

The speed of rollers in the cassette determine the aspiration flow and can be set on the machine in ml/min. Aspiration flow can only occur when the tip is not fully obstructed. When the the phacotip is fully occluded, there is no flow. The actual flow passing through the aspiration line is dependent on the force of the phacopump pulling the fluid, and the total resistance in the aspiration line. Pump capacities and aspiration line lumen sizes vary among the available phaco machines. The preset values displayed on the machines do not necessarily occur in real time. A good example is that the aspiration flow at the same machine setting of e.g. 50 ml/min can be close to that value with a large bore phacotip of 0.7mm and a normally large lumen aspiration tubing. In contrast, the preset value of 50 ml/min will not be reached through the very small 0.3mm port of the I/A aspiration port opening. This can be easily less than half of that value, depending on the system specifications.

Vacuum

The vacuum, which is displayed on the machine is the preset maximum level. When the tip is occluded, the pump rollers will continue to spin until the preset maximum vacuum level is reached. The time necessary to reach this maximum vacuum level (vacuum rise time) is dependent on the speed of the rollers (aspiration flow setting). The same high vacuum level can be reached either at a high speed/high flow setting or at a slower pace/low flow setting. The maximum vacuum level is lost when the tip occlusion breaks. This normally happens anytime when ultrasound is activated in footswitch position 3. Vacuum is only built up in footswitch position 2 when both irrigation and aspiration occur. (Fig. 5)

Vacuum is the holding force of the machine, which keeps lens material at the tip to be emulsified, and to pull the lens material through the aspiration line. There is always a debate about the required level of vacuum in phaco surgery. In essence it can simplified by the following: high enough to do the job, but not too high because of one potential drawback. This ‘drawback’ phenomenon is “Surge Flow”.

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Surge

The mechanism of Surge Flow only occurs at the moment of occlusion break and vacuum loss. It is very brief moment in a fraction of a second, when the contracted aspiration line under vacuum, suddenly springs back to its original shape and volume when vacuum is lost. (Fig. 6 - 9)

The severity of the surge flow is determined by the following factors:

- Vacuum; surge increases with higher vacuum
- Phacotip lumen; a smaller lumen will restrict the amount of fluid during the surge
- Sleeve size; a larger sleeve will allow more fluid into the eye during surge
- Infusion pressure; a higher bottle will push more fluid in the eye during surge
- Compliance of tubing; softer tubing material will contract more resulting in higher surge

Beware of Air!

When a significant amount of air is inadvertently aspirated, the post occlusion surge response can be dramatically higher because air is much more compliant than fluid. The air in the aspiration line will enlarge significantly under vacuum. On occlusion break, the air will return to its original volume, markedly adding to the force of the surge. Air is easily aspirated when the phaco tip is retracted from the eye while in footswitch position 2. This happens often, and many surgeons are unaware of the danger. If air is aspirated inadvertently, one must place the phacotip in a fluid container and aspirate fluid until the air has emptied completely from the aspiration line.

Hydrodissection

There is a consensus among ophthalmologists regarding the necessity of adequate hydrodissection prior to nucleus disassembly and emulsification. For phaco-chop and divide-and-conquer techniques, the lens must be completely mobilized to allow easy nucleus rotation. Hydrodissection should result in a fluid wave travelling completely across the posterior surface of the lens. This ensures that complete dissection of the lens from the posterior capsule has occurred. Hydrodissection cannulas of various designs are used to accomplish the dissection.
I have noticed that many colleagues do not intentionally separate the lens from the anterior capsule. If these connections are not adequately separated, the lens will be unable to rotate. In this article, I describe my method for dissecting anterior capsular connections. Residents in our clinic learn this method without significant difficulty. This is a simple and logical technique that many surgeons may already practice.

**Technique**

After a complete posterior fluid wave crosses the entire posterior surface of the lens (Figure 21), depress the nucleus, which will subsequently separate itself from the anterior capsule at approximately the 4- or 5-o’clock position (Figure 22 + 24). As you press on the nucleus, fluid underneath the nucleus will shift to the opposite side. Next, depress the nucleus on the opposite side (Figure 23+25). The nucleus can move a little posteriorly into the accumulated fluid pool, separating itself further from the anterior capsule. If the anterior capsule remains in position when the nucleus is pressed downward close to the anterior capsulorhexis edge (Figure 4), this means that the anterior capsule and lens have separated. If one observes this separation at opposite sides of the lens, the anterior connections should be sufficiently dissected to allow easy rotation.

**Soft Lenses**

Although dense cataracts and narrow pupil cases are considered to be difficult for novice surgeons, soft lenses can be problematic for inexperienced surgeons as well. If one tries to crack or chop a soft nucleus in a conventional way, the cracking instrument does not meet any resistance and slices through the soft lens without splitting it. This can lead to repeated and unnecessary manipulations in the eye with loss of visibility and potential complications as a result.

My recommended technique for soft lens management is:

- Perform a normal hydrodissection and obtain a good cleavage plain circumferentially
- Partial subluxation of soft lens material into the anterior chamber is part of the strategy and should not be attempted to stop or redress (Fig. 26)
- Subsequently inject fluid in a multiple cortex layers to create multi-hydrodelineation circles, resembling the anatomy of an onion (Fig. 27)
- Significant soft lens mass will have protruded into the anterior chamber, which facilitates the next lens removal step
- Introduce the phaco tip in a bevel down position to create a direct aspiration contact with the lens

Utilize so called “Epinucleus” settings, which encompass (Fig. 28)

- moderate vacuum to reduce potential surge
- moderate aspiration flow
- linear flow and vacuum settings, which enables you to very slowly aspirate the soft lens into the phacotip and as the lens is nicely molded in the tip, the footswitch can be depressed progressively to aspirate the lens
- low ultrasound power limit

The linear flow and vacuum control is essential for controlling the aspiration of a soft lens

Fig. 26  Fig. 27  Fig. 28
1. Anesthesia

There are various types of anesthesia that can be used in cataract surgery: general, retrobulbar, peribulbar, sub-Tenon (or: parabulbar), subconjunctival, and topical corneoconjunctival anesthesia.

In retrobulbar anesthesia, the anesthetic is delivered behind the bulbus thereby providing akinesia (of especially the rectus muscles and the inferior oblique muscle), anesthesia (by anesthetizing the ciliary nerve), and anopsia (due to anesthesia of the optic nerve). Possible complications of retrobulbar anesthesia are optic nerve injury, brainstem anesthesia, and globe penetration (in and out). In myopic eyes, the risk for globe penetration may be 1:140. In addition, extraocular muscles may be damaged due to anesthesia myotoxicity or direct needle trauma. In addition, a much-feared complication is a retrobulbar hemorrhage that may occur in up to 0.44% of cases (Edge KR, Nicoll JMV. Anesth Analg 1993;76:1019-1022). This complication may be sight threatening if not detected early and treated early and properly. A lateral canthotomy and cantholysis may be needed to perform.

In sub-Tenon anesthesia, an incision is made in the conjunctiva and Tenon to gain access to the sub-Tenon space. With blunt scissors, the Tenon is dissected from the bulbus to gain access to the parabulbar space. Then, using a curved blunt needle, anesthetic (such as
lidocaine 1% for intrathecal or intravenous use) is injected. Sub-Tenon anesthesia provides good anesthesia but often only limited akinesia. Anopsia is only rarely achieved. Depending on the used technique, the conjunctiva may be very swollen and hemorrhagic.

**Topical anesthesia** is often achieved with tetracaine or oxybuprocaine eye drops. Intracameral injection of lidocaine (1%) at the start of surgery provides additional anesthesia and thus comfort for the patient. Of course, akinesia and anopsia is not achieved with this type of anesthesia. For beginning surgeons, it is important to understand that topical anesthesia provides adequate anesthesia up to approximately half an hour. Contraindications for topical anesthesia depend on the skills of the surgeon, the type of operation, and the cooperation of the patient. Relative contraindications are a language barrier, deafness, uncooperative patients (for example in whom it is not possible to measure IOP), anticipated difficult surgery (e.g., mature cataract, zonulolysis), an anticipated longer surgery time (i.e., more than 30’), and nystagmus. Absolute contraindications are allergies to the used anesthetics and coarse nystagmus. For maximum cooperation by the patient, use as little light for the operating microscope as is safely possible. Also, beware of irrigating the cornea because the patient may move their eyes. In addition, under topical anesthesia the patient is more aware of what you do. Therefore, tell the patient what you are doing and give clear instructions what you expect him/her to do. This is called *verbal anesthesia*. In a deep-set eye, let the patient tilt their head with the chin up in the air (a little overstretched) and ask them to look down to their toes to improve approach of the main incision.

2. **Incisions**

Incisions in cataract surgery are intended to allow entrance into the eye. There are several types of incisions; they are named after the location of the incision. Examples are scleral (also referred to as sclerocorneal or corneoscleral), limbal, near-clear corneal and clear corneal.

![Incisions in cataract surgery](image)

Corneal incisions are nowadays most often used in cataract surgery. They are fast to construct, strong if constructed well. They may, however, have an increased risk of endophthalmitis, although this may be related to the construction of the incision. The corneal flattening effect (surgically induced astigmatism, SiA) is between 0.20 D and 0.80 D for a 2.2-mm and 2.8-mm incision, respectively. Scleral incisions take more time to construct. However, they are very strong with a low risk of Seidelings. The average effect on astigmatism is zero. However, it may vary considerably (and even more than in corneal incisions) between patients!
There are several ways to construct an incision: a single-plane incision, a biplanar (two-step) incision, and a 3-step incision. The single-plane incision is the fastest to construct. However, the external edge of the incision is more prone to tearing and therefore may be less stable.

To create a **biplanar (2-step) incision**, for a right-handed surgeon, the main incision is to be made at the 100° position (11:30 clock hours) so that it is easily accessible for the surgeon’s dominant hand. First, a groove is made in the cornea with the main incision knife’s right side of the blade 1 mm anterior to the limbus and parallel to the limbus. Next, the tip of the blade is placed through the groove in the corneal stroma. Hold the blade parallel to the iris plane and gently push the blade forward through the stroma. The blade will pass through Descemet’s membrane and enter the anterior chamber. Withdraw the keratome when the widest part of the its blade has passed the inner part of the incision. If the anterior chamber has shallowed because of leakage of aqueous through the newly-created main incision, reform the chamber with OVD.

To create a **three-step incision**, for a right-handed surgeon, the main incision is to be made at the 100° position. First create (if necessary) a limbus-based peritomy of the conjunctiva and Tenon’s layer. To this end, uphold the conjunctiva with fixation forceps and incise the conjunctiva approaching it from the caudal part. Dissect the conjunctiva posteriorly to expose sclera for 2 clock hours. Then, make a straight groove in the sclera (with the main incision knife’s right side of the blade) 1-2 mm posterior to the limbus and parallel to the
limbus. Next, tunnel into the clear cornea. When the tip of the blade is in the clear cornea, push the blade through the cornea until it is 2 mm into the wound. Then, tilt the knife and point toward the macula and incise through Descemet’s membrane and enter the anterior chamber. Withdraw the keratome when its widest part has passed the inner part of the incision.

Some tips for creating the main incisions: maintain appropriate pressure in the anterior chamber (with ophthalmic viscosurgical device [OVD]). Underpressure will lead to a tunnel that is too long and an irregular edge of the wound; overpressure will lead to a tunnel that is too short. In addition, when in doubt, perform a Seidel test with a fluorescein strip to test for leakage and suture the incision if necessary. Furthermore, fixate the eye by grasping the conjunctiva at the limbus with forceps (e.g., a Hoskin 22).

For bimanual irrigation and aspiration (I/A), create one side port incision (paracentesis) with the side port knife at 30° (2 clock hour) and one at 150° (10 clock hour). These locations are known as the fork-and-knife position. The angle between the main incision and the left side port incision should be less than 90°. To this end, place the tip of the knife in the clear cornea just anterior to the limbus. The tip of the knife should point toward the center of the anterior capsule. Push the blade through the cornea until its widest part has passed through the cornea. Refill the anterior chamber with OVD, if necessary.

3. Capsulorhexis and risk for tear-out and management

The continuous curvilinear capsulorhexis (CCC) allows removal of the lens from the lensbag. The circularity of the rhexis makes it very strong and resistant to tearing out. Capsulorhexis means tearing of the capsule; capsulotomy means cutting of the capsule (e.g., used in femtosecond-laser assisted cataract surgery [FLACS]), and capsulectomy means cutting out of the capsule (e.g., with scissors).

The capsulorhexis can be created with either a cystotome (a bent needle with a sharp tip) or a capsulorhexis forceps. To create a capsulorhexis with a needle, place the tip of the capsulorhexis needle at the center of the anterior capsule. Make a 3-mm long incision in the anterior capsule toward the 2 o’clock position. Then, place the tip of the needle at two-thirds of the distance between the center and the peripheral end under the anterior capsule and gently lift it up. While lifting the capsule, direct the needle toward the 6 o’clock position.
thereby creating a flap. With the tip of the needle, gently push the capsule in a circular fashion.

With a capsulorhexis forceps, my technique is to make a straight incision into the anterior lens capsule with the tip of the forceps. Then, I grab the anterior capsule on the left side of the incision and tear it in a circular motion anti-clockwise. I believe it is a personal preference to use a clockwise or anti-clockwise motion. Similarly to using a cystotome to create the capsulorhexis, it is important to regrasp the capsule often.

During construction of the capsulorhexis, the rhexis may tear out. This is due to the fact that the lens’ surface is not flat; this will always induce a tearing-out of the rhexis. Actually, this is one of the main reasons to use OVD: the pressure of the OVD flattens the lens’ surface and thereby minimizes the risk of a tear-out. When the rhexis does tend to tear out, this may be due to a lowered pressure in the anterior chamber because of positive intralenticular pressure or positive vitreous pressure. In addition, it may be due to leakage of OVD out of the eye. When one notices the rhexis to start tearing out, one needs to refill the anterior chamber with OVD. In addition, positive intralenticular and/or vitreous pressure needs to be cancelled. Then, the rhexis is pulled along the margin of the pupil and subsequently again centripetally. When the rhexis runs out into the zonules, Brian Little’s capsulorhexis tear-out retrieval technique should be performed. To this end, the rhexis’ flap is laid out flat on the lens. The flap is then grasped at the site where it attaches to the lens capsule with a capsulorhexis forceps. Then, one pulls backward and a little bit centripetally. This will make the rhexis to run centrally again, thereby saving the continuous curvilinear capsulorhexis and prevent a posterior capsule tear.

4. Nucleus management, cracking techniques

Nucleofractis is the maneuver of fracturing the lens into smaller pieces. This is to allow a 10-mm wide lens go through the capsulorhexis with a diameter of approximately 5 mm. The basic technique that is taught to every beginning surgeon is the divide-and-conquer technique. In this technique, 4 quadrants are made that are subsequently emulsified with the phaco tip. To be able to crack the lens into separate fragments, it is important to have performed a good hydrodissection. In addition, the trenches that are used to crack the lens must be of sufficient depth and length. When the trench is sculpted, one passes through the rings of the nucleus. This provides the aspect of parallel lines that are orthogonal to the trench. When one exits the nucleus and enters the cortex, the parallel lines disappear because the cortex is not a layered structure. When this occurs, you know that you are at the right depth to be able to crack the lens.

To crack the lens efficiently, one should put the instruments at the bottom of the trench. Then, the two fragments can be separated with the instruments. An often-made mistake is to have the tips of the instruments too high in the trench. In this way, the trench will open like a book and prevent the back of the lens from cracking.
Cracking of the lens can be done with the instruments crossed or parallel. It depends on the experience and preference of the surgeon which one uses. In soft lenses, in which there is little resistance to pressure from the instruments, parallel cracking is often preferred. With crossed cracking, the trench should be in line with the main incision so as not to distort the main incision too much with the phaco tip. With parallel cracking, the trench should be somewhere in between the main incision and the left sideport.