Phacoemulsification - Fluidics and Phacodynamics

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Common Terminology

Fluidics

Is a science or technology dealing with a control of a flow of fluid or air through a system.

Phacodynamics

Is a branch of mechanics dealing with the motion of fluid and material bodies under the action of given forces.

Irrigation

- Flow of fluid into the eye
- Dependent and determined by bottle height
- Must be equal to or greater than outflow in order to prevent shallowing or collapse of AC
- Outflow includes leakage from wound + paracentesis + aspiration flow rate

Aspiration flow rate (AFR)

- Rate at which fluid is removed from the eye.
- Controlled by pump speed
- measured in cc/min.
- AFR determines the speed of the rise of aspiration vacuum when the tip is occluded

Vacuum

- Negative pressure in aspiration line
- measured in mm of Hg
- Vacuum level created at the port is inversely proportional to the diameter of the tip
- Vacuum holds the material to the phaco tip
- Vacuum = AFR x Resistance, therefore in high AFR systems vacuum is active always when the resistance (occlusion) at the phocotip remains constant (Venturi)

Compliance

- Collapse of the aspiration line when under negative pressure
- Higher compliance results in greater surge amplitude during occlusion break

Surge Amplitude

- Negative force created at phaco tip immediately following occlusion break resulting in fast flow of fluid into the aspiration port.
- Directly proportional to tube compliance
- Higher in systems which contain air due to "spring" action of air columns under pressure... more in Venturi system.

Venting

- Release of residual pressure in aspiration line.
- It is activated upon release of foot pedal
- With momentary opening of aspiration line to air or fluid
- Releases tissue which is against the tip but not in the aspiration port.

Reflux

- Backward flow of fluid into the eye from the aspiration line
- Used to release material which is caught in the aspiration port

Phaco Power (Ultrasonic Power)

- Related to stroke length, frequency, efficiency of the phaco hand piece.
- Stroke length is the to and fro excursion of the phaco tip
- Greater stroke length = higher phaco power
- Frequency is the maximum number of times the tip moves per second, has impact on cutting effect
- Research is on to determine ideal frequency
- Ranges from 27-64 kHz: Storz 28, Nidek 60, Alcon and Allergan 40.

Followability (Holding Power)

- The tendency of the nucleus or fragments to be attracted to and stay on the end of the phaco tip

Chatter

- Too little power will fail to cut the nucleus, too much power will cause chatter
- Reduce power - if the nucleus chatters, change to pulse mode... holds the nucleus better.
- Increase AFR... good followability.

Pump Types

- Venturi
- Diaphragmatic
- Peristaltic

Venturi

- Operates on Bernoulli's principle
- Needs compressed air or gas
- Followability is excellent
- Builds linear, consistent vacuum, utilizes high AFR, live vacuum system.
- Rise time is too fast - least safety margin, vacuum builds up without occlusion
- Iris chaffing and PCR incidences are pretty high
- Zero or high vacuum phaco is not possible
- A lot of air is in the system, air columns act like springs when under pressure.

Diaphragmatic

- Uses a flexible membrane within a cassette to generate vacuum
- Flow rate and aspiration are faster - POOR SAFETY MARGIN
- Tissues can be pulled towards the center while the vacuum builds up even without occlusion
- Good for posterior segment surgery
- Vacuum buildup is linear and reaches preset level without occlusion - UNSAFE
- Rise of Vacuum depends on the fluid in the chamber

Peristaltic

- Operates by "milking" of aspiration line
- No pressurized air or gas
- There is no air in the system unlike Venturi pump
- AFR and vacuum are separate
- Vacuum rise time dependent on AFR and only upon occlusion
- Vacuum fall time NOT surgeon defendant
- Utilizes constant and low/high AFR
- Allows for more predictable response
- Most forgiving system - VERY SAFE

Ultrasonic Hand piece

1. Magneto-restrictive hand piece
    - Uses electric current to induce a magnetic field which results in linear movement of the tip
    - Unbreakable, can be repaired, heavier.
    - Water-cooled, power delivery poor.
2. Piezoelectric hand piece
    - Uses electric current to reorient the piezoelectric crystals
    - Lighter
    - Air-cooled
    - Efficient power delivery
    - Fragile and breakable
    - Not repairable??

Max-Vac System

- Reduced tube lumen (small bore tubing)
- Reduces tube compliance
- Resulting in decreased surge amplitude and therefore safer phaco at higher vacuum settings.

Micro-tip versus Standard-tip

- 0.9 mm vs. 1.1 mm outside diameter
- 0.6 mm vs. 0.9 lumen diameter
- Redesigned irrigation sleeve for more effective and safer irrigation
- Resulting better visibility, maneuverability and reduced surge amplitude

Surge Amplitude Micro tip MV fluidics

- Surge amplitude tends to increase rise in vacuum. But with the combination of Micro tip and Max Vac system the surge amplitude is relatively low at high vacuum settings.

Understand what's happening at the tip. A small change can make a big difference. For example...

- Going from 1.1 mm to 0.9 mm tip. Tip surface area changes from 0.657 sq.mm to 0.343 sq.mm
- Holding power at 120 mm Hg goes from 79 to 41
- With a micro tip vacuum must be increased to 230 mm Hg to have the same holding power as with a regular size tip at 120 mm Hg

What is the relation between AFR and U/S power relative to followability and chatter?

Followability vs. chatter

- We often come across a situation like this... acquire fragment in foot position 2 (aspiration), withdraw to safe location, moment we got to position 3 (U/S), the fragment flies off the tip.
- This phenomenon is called chatter
- Why?
    - Because AFR relative to U/S power is too low
    - Vacuum has yet to build to high enough level to be able to hold the fragment
- So, what is the solution?
    - Increase the AFR to overcome U/S forces
        - One can program a separate AFR setting for position 3 in certain machines.
    - Decrease U/S power setting
    - Wait for higher vacuum to build up in foot position 2 before going to 3

How does the phaco tip actually cut the lens?

- Mechanical impact of the tip against the lens at the end of the stroke
- Shock of the acoustic wave transmitted through the fluid in front of the tip
- Impact of fluid and lens particles being pushed forward in front of the tip
- Cavitation: on retraction of the tip a void is created in the fluid which collapses by implosion - creating an additional shock wave.

Secrets to successful phacoemulsification

- Don't hesitate to accept the technology
- Be bold and take a plunge (swimming)
- Understand the technology available to you
- Go slow be patient and follow the masters
- Always remember the important tips regarding vacuum, flow rate and power

Hi Vac 100+

- Strong holding power

Applications

- Maximum effect with occlusion
- Quadrant/Segment removal
- Thick epinucleus
- Nuclear rim

Advantages

- Rapid tissue removal
- Efficient emulsification
- Nucleus and its fragments can be controlled better

Considerations

- Chamber maintenance is relatively difficult. Not for transition surgeons
- More turbulence. Potential tissue damage is greater. Calls for dexterity.

Low Vac

- Low holding power

Applications

- Sculpting
- Soft nucleus
- Epinucleus with good hydrodissection
- Complicated cases

Advantages

- It is a controlled procedure
- Turbulence is less
- With improved chamber maintenance

Considerations

- Less holding power
- Increase U/S time
- Less tissue control
- Soft nucleus can occlude and refuse to budge

Zero Vac

- Minimal holding power

Applications

- Good for sculpting, shaving. Does not drag the nucleus/capsule. Tear (non-occlusion)
- Good for soft nucleus
- Complicated cases

Advantages

- Facilitates deep and peripheral sculpting
- Eliminates potential for unwanted tissue purchase
- Facilitates emulsification
- Chamber maintenance is greatly improved

Considerations

- One must be careful regarding thermal burns to the incision
- Safety margin is reduced - wound burn
- Practically there is very little outflow
- No holding power
- Only sculpting of the nucleus is possible

Hi Asp Rate

- Attracts the tissue to the phaco tip faster

Applications

- Quadrant/Segment removal

Advantage

- Fast occlusion rate
- rapid tissue removal
- Excellent followability
- Fast rise time - everything is quick

Considerations

- Advanced phaco surgeons

- Turbulence is relatively increased
- Chamber maintenance is a sometimes difficult
- Surgeon's reaction time is decreased - mishaps

Low Asp Rate

- Slow attraction of tissues to the tip

Applications

- Soft tissue
- Sculpting
- Epinucleus
- Complicated cases

Advantages

- Controlled occlusion
- Slower, controlled followability
- Chamber maintenance is relatively easier

Considerations

- Slow rise time - well within control
- Good for transition surgeons

Hi U/S Power

- Longer stroke length
- Increased cavitiation and emulsification

Applications

- Initial sculpting
- Specially hard nucleus

Advantages

- Improves the cutting power with hard nucleus
- Rapidly removes the tissues

Considerations

- May repel quadrants/segments and cause chatter
- Requires high vacuum to minimize chatter
- There is a high potential for thermal injury to the incision

Low U/S Power

- Shorter stroke length
- Less cavitation and emulsification

Applications

- Sculpting of soft nucleus
- Epinucleus
- Quadrant/segment removal
- Nuclear rim removal
- Complicated cases
- Deep sculpting

Advantages

- Improved followability
- There is controlled tissue removal
- Less turbulence

Considerations

- Low U/S power not recommended for 4+ nucleus
- Decreased emulsification
- Utilize KELMAN TURBSOSONICS tip for harder nucleus

Pulse U/S Power

- Intermittent u/s stroke

Applications

- Quadrant/segment removal
- Nuclear rim removal
- Nuclear plate removal

Advantages

- Increased followability
- Lower U/s power required
- Thermal burns are reduces considerably

Considerations

- If power and pulse are too high, you may push nucleus away which might cause PCR.
