Principles of Phacoemulsification

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Charles D Kelman MD
1930-2004
- "Father of Phacoemulsification"
- 1962 - invented cryoprobe
- 1966 - first animal phaco
- 1967 - first human phaco
  - 76 minute phaco time
  - Inspired by dental unit

Phacoemulsification
- Technology and techniques are rapidly evolving

This is a technology driven procedure
You get what you pay for
**Phacoemulsification**

- Handle
  - Ultrasonic energy
- Fluidics
  - Irrigation
  - Bottle height
  - Aspiration
  - Flow rate
  - Vacuum
- Foot Pedal
  - Controls device

**Phacoemulsification**

- Ultrasonic phaco
  - Electrical energy converted into mechanical energy
  - Tip vibration
  - Generates friction which creates heat - thermal damage

**Phacoemulsification**

- Older generation machines
  - More energy
  - Increased thermal damage

**Phacoemulsification**

- Reuseable tips & tubing
- Cost effective?
- How do you clean and sterilize???
- Disposables
  - $/patient
Should you re-use your materials?

- Sterilization
  - **Do Not** gas your tubing or handpieces
  - Gas does not sterilize areas that are wet or have trapped liquid
  - Clean after each use
    - Distilled water
    - Steam autoclave
    - Routine
    - Flash

Phacoemulsification

- Power controlled by frequency and stroke length
- Frequency
  - 35,000 - 45,000 cycles/sec (Hz)
  - Lower frequency = less efficient
  - Higher frequency = excess heat

- Stroke length
  - 2-6 mil (thousands of an inch)
  - Most operate at 2-4 mil
    - (0.1-0.12mm)
  - Longer the stroke length
    - Increased heat
    - Increased cavitation
    - Increased physical impact on lens

Phacoemulsification

- Emulsification of lens
  - Jackhammer
    - Physically striking the lens
  - Cavitation
    - "The formation and immediate implosion of bubbles in a liquid"
    - High and low pressures
    - Microbubbles
    - Implosion of microbubbles
    - Temperature at implosion of 13000° F
    - Shockwave at implosion 75,000 PSI

Phacoemulsification

- Cavitation
  - Cavitation Bubbles
  - Cataract Material
  - Phaco Tip
Phacoemulsification

- **Transducer**
  - 40,000 cycles per second
  - Power related to stroke length
- **Destructive events**
  - Cavitation
  - Fluid and lens particles at tip reach velocities of 72 km/hr
  - Shock of the acoustical wave
  - Mechanical impact of tip against lens

Phacoemulsification

- **15,30,45 degree cutting tips**
- **45 degree - improved cutting efficiency, more difficult to occlude**
- **Flare tips**
- **Angled tips - Kelman**
Angle of the tip can be varied to facilitate occlusion

Phacoemulsification

- Minimal phaco energy is desired
  - Stroke length
  - Preset
  - Foot pedal
  - Duration
    - Efficient surgeon
    - Pulse or burst mode
    - Emission
      - Tip selection
        - Kelman
        - Flared
        - 0, 15, 30, 45 degree

Preset

- 100%
- 50%
Phacoemulsification

- Kelman tip
  - Hard nuclei
- Flare tip
  - Direct cavitation into tip

**VORTEX Phaco Tips**

Phacoemulsification

- Fluidics
  - Inflow
    - Bottle height
  - Outflow
    - Incision
    - Aspiration rate
    - Vacuum preset and demanded

Phacoemulsification

- Fluidics
  - Irislation
    - Cooling at incision
    - Maintain the anterior chamber
  - Aspiration
    - Aspiration flow in ml/minute
    - Vacuum in mmHg

Infusion bottle height - every 15cm above the eye = 11mmHg

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Phacoemulsification

- Fluidics
  - Peristaltic
    - Wheel with rotating bearings
  - Venturi
    - Compressed gas
  - Diaphragm
    - Piston and valve
  - Hybrid

**CENTURION VISION SYSTEM**

Active fluidics
Phacoemulsification

- **Irrigation/Aspiration**
  - **Peristaltic**
    - Wheel with rotating bearings
  - **Diaphragm**
    - Piston and valve
  - **Venturi**
    - Compressed gas

Diaphragm

Phacoemulsification

- Peristaltic pumps “safer” as they take several seconds to build to preset vacuum
  - More forgiving
- Diaphragm and Venturi pumps give preset vacuum immediately
  - More responsive
  - Better for posterior segment work

Know where the aspiration reversal switch is
Phacoemulsification

- Aspiration reversal

How to “Set the Dials”?
- Goal is a “stable” eye. Not too soft, not too hard
- Just Right

Vacuum Settings

- Standard Phaco
  - 20 mmHg min
  - 70 mmHg max

- Phaco Pulse
  - 28 mmHg min
  - 220-300 mmHg max

- I/A
  - 26 mmHg min
  - 300 mmHg max

Vacuum

- Do not need high vacuum when sculpting as lens is stable
- Higher vacuum for cracking, chopping and fragments to “hold” will allow lower phaco energy

Tip occlusion
Phacoemulsification

- Surge
  - Tip occlusion followed by fragmentation and immediate aspiration
  - Shallowing of the chamber
  - Newer technology addresses this
    - Microprocessors sample vacuum/flow 50 times/sec

Higher the vacuum the greater the surge effect

Evaluation of fluid leakage into the canine vitreous humor during phacoemulsification using contrast-enhanced magnetic resonance imaging


Department of Ophthalmology, Graduate School of Medicine, University of Tokyo, Japan

Objective: To evaluate the effects of phacoemulsification with different fluid patterns on the intravitreal tissue using contrast-enhanced magnetic resonance imaging (CE-MRI).

Methods: Phacoemulsification with intravenous fluid (IVF) implantation was performed in 10 pairs of enucleated canine eyes. The irrigation fluid was used with the binaural irrigation system set at 30 cmHg with 70% saline, and the irrigation fluid flow rate was set at 200 ml/min. The intraocular pressure was maintained at 50 mmHg, and the suction rate was set at 80 mmHg. The US time was 2 minutes, and the inflation time was 1 minute.

Results: CE-MRI revealed fluid leakage into the vitreous cavity and anterior hyaloid detachment in all eyes. The amount of fluid leakage was significantly greater in Group H compared to Group L. The amount of vitroretinal leakage was also significantly greater in Group H compared to Group L. The amount of fluid leakage was significantly greater in Group L compared to Group H.

Conclusions: Fluid leakage into the vitreous cavity and anterior hyaloid detachment during phacoemulsification can be significantly reduced by using a different fluid pattern. Further studies are needed to investigate the optimal fluid pattern and injection timing during phacoemulsification.

Group L
- 50 mm bottle height
- Suction 50 mmHg
- US time 117 +/-12s
- Volume 165 +/- 54ml

Group H
- 120 mm bottle height
- Suction 80 mmHg
- US time 96 +/-31s
- Volume 255 +/- 33ml

Fluid in vitreous and anterior hyaloid detachment
Fluid in the vitreous
- Worse opposite entry site
- > with longer irrigation time
- > with increased fluidics
  - Bottle height
  - Vacuum

Would stage of cataract and state of vitreous affect this?
Could be associated with:
- Retinal detachment
- Vitreous contamination and endophthalmitis

Phacoemulsification

- Pulse/Burst Mode
  - Decrease overall power delivery
  - Provides deeper more stable A/C
  - I choose to increase vacuum setting to 300-350 mmHg max setting
  - Think of increased vacuum as an extra hand in the eye to hold and pull the sculpted lens apart

Phacoemulsification

- Pulse/Burst Mode
  - Pulse - Alcon Legacy
    - 50-150 msec of power followed by variable period of aspiration only
  - Burst - Allergan Sovereign
    - 80-120 msec of power followed by fixed short period of aspiration

Phacoemulsification

- Whitestar®, Hyperpulse® technology
  - “Cold Phaco”
  - Instead of 2-6 pulse/sec get 50 microbursts/sec
  - No time to create thermal effect
  - Minimal cavitation

Phacoemulsification
Pulse Phaco

K9 unstable lens
Coaxial standard phaco
vs.
High vacuum pulse phaco (350 mmHg)

Watch the lens movement decrease when switched to high vacuum.

Hydrodissection

- Inject BSS between capsule and cortex
- Separates posterior cortex/nucleus from the posterior capsule

Hydrodissection

- Better for 2-handed technique
- Divide & conquer
- Chip & flip
- Phaco chop
- CTR placement in unstable lens
- Lens free to rotate in the capsule bag
- Less desirable for one-handed coaxial phaco
Hydrodissection + CTR

Hydrodissection

Hydrodelineation
- Injection of BSS into nucleus
- Separates nucleus from the epinucleus
  - Used for hard nucleus so epinucleus protects capsule

Phacoemulsification
- Trauma
- Time
  - Surgery time - 10-17 minutes/eye
  - Phaco time - 0-120 seconds/eye
- Fluid Volume
  - 50-200 ml/eye
- Turbulence
- Phaco Energy
- Chamber bounce

Intraocular Surgery
- “The enemy of GOOD is BETTER”

Phacoemulsification
- Surgeon must be adaptable
  - Know more than 1 technique
  - No one single method works on all cataracts
**Phacoemulsification**

- Divide and conquer
- Chip and Flip
- Croissant
- Phaco Chop
- Stop and Chop
- Other

**Phacoemulsification**

- One handed vs two handed technique

Zonules are like corn silk. They entwine and extend far posterior.

Pull on the lens.....
You pull on the zonules....
You pull on the ora...
You pull on the ora....
You pull on the retina...

And it may lead to...
Retinal tears, detachment.

**Phacoemulsification**

- One-handed technique
  - Sculpt a large, deep bowl
    - Rotate lens and divide & conquer
  - Crack the bowl
    - Increase suction, use pulse
  - Flip bowl over to phaco posterior aspect
    - Pressure at near side, push down and away
    - Use suction to pull bowl over as it flips
One-handed technique

Pulse setting, Vacuum 300 mmHg
6 Year – old Diabetic Dog
Phaco -37 sec, 120ml

Phacoemulsification
- Two-handed
  - Hard nuclei
  - Unstable lens
  - Shorten surgical time and decrease phaco power

Lens Subluxation/Luxation
- Zonular dehiscence <120 degrees
  - 2-handed phacoemulsification
  - Hydro-dissection + CTR and IOL in the bag IOL or Sutured IOL
- Zonular dehiscence >120 degrees
  - 2-handed phacoemulsification or ICLE
  - Sutured IOL

THIS IS OFTEN AN INTRAOP DECISION

Phacoemulsification
- Two-handed
  - Side-port incision 45°- 90° from coaxial phaco
  - 1mm keratome
  - When to perform?
    - I choose to enter after phaco needle in the eye
    - Can choose to switch mid-surgery
    - Insert rotator, manipulator, chopper
    - Retract into A/C when not in use

Two-handed conversion
- Zonular dehiscence <120 degrees
  - 2-handed phaco
  - Hydro-dissection + CTR and IOL in the bag IOL or Sutured IOL
- Zonular dehiscence >120 degrees
  - 2-handed phaco or ICLE
  - Sutured IOL
Choppers, manipulators

Warren C. Veterans Ophthalmology 7:348-351, 2004
Maggio F, et al. ACVO 2008

Phaco Chop

Divide & Conquer

Two-hand phaco for unstable lens

Divide & Conquer

X X
Incorrect Divide & Conquer

Capsule Tension Ring

- Stabilize the lens capsule when zonular weakness, degeneration, dehiscence is present
- Prevent capsular phimosis
- When to implant?
  - Pre or Post phaco
  - Size selection

Capsule Tension Ring

- Size of CTR matches size of IOL
  - 12mm IOL = 12.5 mm CTR
  - 13mm IOL = 13.5 mm CTR
  - 14mm IOL = 14.5 mm CTR

Capsule Tension Ring

- Risks of CTR implantation?
  - 47 dogs, 94 eyes
  - One receives CTR, other is control
  - 1 yr follow up
  - No signif diff CTR vs no-CTR

Veterinary Ophthalmology 11:426, 2008
CTR Pre-phaco

Zonular dehiscence >120 degrees

240 degree instability-2 handed

300 degree Anterior luxation
Two Handed with vitrectomy and ECP

Pre-op IOP 32 mmHg

Complete Lens Luxation - anterior/posterior

Personally – I always try to remove by phaco. I NEVER use a cryo-technique

Medical vs Surgical
- Posterior entrapment plus a miotic
- No significant mean time to glaucoma or vision loss
Phaco vs ICLE

- Better vision preservation with surgery vs. medical for subluxation vs luxation
- Better success for Phaco vs ICLE
- Retinal detachment
  - 28% with ICLE
  - 6% with Phaco
- Glaucoma
  - 60% have IOP concerns longterm -ECP


O’ Malley Lens

K9 Posterior lens luxation 2-hand phaco

Want a high viscosity visco like 2% Acri-Syn

Sabet® Lenticular Safety Net

Cortical Aspiration

- ≥0.5 mm port required for canine cortex
Cortical Aspiration

Cortical I/A 0.5mm curved

Cortical I/A

Bi- Manual Cortical I/A

Bi-Manual Cortical I/A

Residual lens cortex material: Potential risk factor for endophthalmitis after phacoemulsification cataract surgery

Capsule Vacuum

Value of this step??
Capsule vacuum

Capsule polish

Whitman Shepherd Capsule Polisher

- Removal of Viscoelastic

AcriVet 60V IOL

Forceps fold acrylic IOL

Modified ab-externo IOL

Ventral suture placement
Dorsal suture placement - PMMA IOL

Dorsal suture placement - Duet® Forceps

IOL Placement

Suture Fixation

Modified ab-externo Cow Hitch Technique

Acrivet Acrylic IOL for Modified ab-externo cow-hitch technique
Acrivet Acrylic IOL for Modified ab-externo cow-hitch technique

Ozil® torsional phaco

Phacoemulsification

- Change is difficult, but not always bad
- We are now the “conventional surgeons” and newer technologies are challenging us

My new residents!!
INDIVIDUALITY
Always remember that you are unique. Just like everyone else.