I. Cataract and Glaucoma - Important Issues

A. Commonly coexist and present special problems: As our population ages, ophthalmologists must be prepared to simultaneously manage cataract and glaucoma. Indeed, decisions related to the lens will increasingly play a role in the management of glaucoma. Certain management issues are unique to either cataract or glaucoma and others share common concerns.

B. Cataract assessment: determine need for cataract operation - can be difficult with a miotic pupil and pre-existing glaucomatous optic nerve damage. Assess with maximal dilation, potential acuity testing, brightness acuity testing.

C. Glaucoma assessment: determine type of glaucoma (i.e., OAG, PXF, angle closure) and access degree of optic nerve damage - can be difficult because cataract may affect visual field testing, alter view of optic nerve and may even be an infrequent cause of glaucoma. Assessment of extent of glaucoma damage is critical for decision-making. Visual fields may “improve” after cataract surgery (Ang et al).

D. Risks and complications greater with cataract surgery in glaucomatous eyes than in non-glaucomatous eyes due to: miotic pupil, posterior synechiae, PAS, CACG; congested eye - bleeding, previous surgery - scarring or pre-existing bleb, associated systemic diseases - diabetes, associated eye conditions –myopia; crowded anterior chamber – high hyperopia, nanophthalmos increased incidence of post-op IOP rise, increased incidence of suprachoroidal hemorrhage. CME may increase with use of multiple glaucoma meds incorporating BAK (benzalkonium chloride) preservative. Pseudoexfoliation (PXE) underappreciated as a risk factor: higher risk of zonular dehiscence, vitreous loss, anterior capsule contraction, IOL dislocation/centration.

E. IOP Effect on Cataract Formation: Elevated IOP may increase risk of nuclear cataract and use of glaucoma meds could magnify this risk (Blue Mountain Eye Study). Low IOP after trabeculectomy is a risk factor for cataract progression.

F. IOP Effect of Cataract Surgery: Small incision phacoemulsification has a statistically significant, but small, IOP lowering effect in normal eyes and glaucoma suspect eyes extending one to five years post-op. Preop IOP level and angle status important. Medication requirements may be reduced in eyes with glaucoma. However, IOP spikes may occur in the first 24-hours post-operatively and occasional patients may have long-term IOP elevation.

G. Glaucoma Medications - compliance, allergy, toxic effect on conjunctiva under-appreciated.

H. Steroid response post-cataract surgery: younger patients with high myopia have higher risk for postoperative steroid response – 35 x greater risk for IOP > 35 mmHg (Chang et al).

I. Laser Trabeculoplasty (LT): Argon Laser Trabeculoplasty (ALT) Selective Laser Trabeculoplasty (SLT) and Micropulse Diode Laser Trabeculoplasty (MLT).

1. Traditional dogma: LT more effective in phakic eyes than aphakic/pseudophakic eyes
   a. Statistically significant difference, but not substantial clinical difference
   b. ALT may still be used after cataract surgery - smaller IOP reduction, but still clinically effective
   c. SLT delayed response in pseudophakia compared to phakic eyes; long-term results similar (Shazly)

2. Indications - decision for ALT/SLT/MLT based on glaucoma status as for any patient, relatively independent of cataract. (See Indications for Combined Surgery.) ALT/SLT/MLT may be performed more often if cataract surgery alone anticipated, rather than combined surgery. Successful ALT/SLT result may rarely permit cessation of miopic, leading to enhanced vision and delay of cataract surgery.

3. If indicated, best performed at least one month prior to cataract surgery.
   a. If ALT, consider treating inferior 180 degrees away from future sclerectomy site
   b. Possible role of ALT in encapsulated bleb formation

4. LT does not blunt early post-op IOP rise after cataract surgery

5. Cataract surgery does not appear to diminish effect of ALT, if performed after ALT.
6. SLT and MLT issues – same as for ALT, but potential for retreatment

7. SLT in PXF: effective as primary treatment and retreatment may be successful (50-60%, MEEI/Tufts study, 2013)

J. Glaucoma Surgery in Pseudophakia: Traditional thinking has suggested that surgical intervention for glaucoma may be less effective in aphakic/pseudophakic eyes than in phakic eyes - this may or may not be true (see III.F.), but must be taken into account when determining initial procedure of choice for co-existing cataract and glaucoma. Motility of conjunctiva important for successful glaucoma surgery

K. Cataract Surgery In Presence of Bleb: Trabeculectomy performed first increases risk of cataract formation. Effect of subsequent phaco procedure on increasing IOP must be taken into account

L. Controversies:
   1. One or two procedures: phaco first, glaucoma procedure second; glaucoma procedure first, phaco second vs combined procedure
   2. One-site or two-site combined procedure
   3. Timing of surgery
   4. Long-term outcomes
   5. Use of non-filter procedures for IOP control – MIGS procedures
   6. IOL choice – use of “lifestyle” IOLs
   7. Laser assisted cataract surgery

M. Surgical options for glaucoma expanding greatly – goal is to avoid bleb dependent IOP control

N. Individualize each case - maximize medical and laser control of IOP, especially in the setting of significant glaucomatous cupping and visual field loss; establish long-term IOP goal for each patient

II. Indications for Surgery - visually significant cataract in presence of glaucoma

A. FIVE SURGICAL OPTIONS
   1. Phaco alone
   2. Phaco “Plus” – MIGS
   3. Phaco with trabeculectomy/tube/canaloplasty – “MAGS”
   4. Two-stage surgery: glaucoma procedure first; phaco second
   5. Pseudophakic filter

B. Cannot be dogmatic or absolute about indications for any of the five options. Must individualize for each patient based on general guidelines. The art and science of medicine must enter the decision-making process

C. AGS Survey of glaucoma specialists (Cohen): Cat/POAG/MTMT/elevated IOP – 70% would perform phaco-trabeculectomy, 22% trabeculectomy, 7% phaco. Cat/POAG/controlled – 84% would perform phaco, 24% phaco-trabeculectomy

D. PHACO ALONE
   1. Advantages
      a. Restore vision promptly *
      b. Single procedure *
      c. Technically easiest - short surgical time
      d. Reduced operative and post-op complications related to wound.
      e. Facilitate post-op assessment of optic nerve and visual field
      f. Opportunity for glaucoma operation later if needed – multiple options conjunctiva can be spared
      g. Small incision phacoemulsification itself can yield improved long-term IOP control (Shingleton, Gamel et al 1 year study; Shingleton, Pasternack et al 5 year study; Suzuki 10 year study; Poley et al, Mansberger et al)
         (1.) Normal and glaucoma suspect eyes have a statistically significant reduction in IOP at 1 year (~2 mm Hg), maintained at 5 years. Significant IOP reduction for glaucoma eyes at 3-5 years
         (2.) Glaucoma eyes have a statistically significant reduction in glaucoma medication requirements at 1 year, gradual increase to preop levels over 5 years
         (3.) IOP reduction may be greatest in eyes with relatively narrower angles preop – greatest proportional change in angle width and depth occurs in eyes with narrow angles or ACG; > 4 mm Hg
IOP reduction may be achieved in narrow angle eyes (Brown)

(4.) P/D ratio: ↑ preop IOP mm Hg/ AC depth ratio (↑IOP/↓ACD) → ↑ IOP reduction. P/D > 7 → ↓ IOP ≥ 4 mm Hg (Issa et al)

(5.) Higher preop IOP → greater IOP reduction (Poley et al)

(6.) PXF eyes (noncomplicated surgery) IOP and GMR reduction similar to primary OAG. (Shingleton, Lau et al): higher pre-op IOP results in greater IOP reduction. PXF eyes with history of prior laser/filter less successful

(7.) Mattox – higher phaco ultrasound power associated with greater IOP reduction

(8.) Mechanism – unknown. Poley et al; Johnstone: possible mechanical effect of removing “thick” cataract with replacement by “thin” IOL results in anatomic opening of angle and physiologic improvement in outflow facility

(9.) Regression to the mean issues. Chang, Budenz et al – 3 year follow up phaco versus no phaco fellow eye; no difference in IOP, meds

2. Disadvantages
   a. Early post-op IOP rise: 1-8 hours post-op and POD #1
      (1.) Peak mean IOP ↑ at 1 hour – 13.4 mm Hg in normal eyes (Rainer et al)
      (2.) Can be significant: 4% of normal eyes and 19% of glaucoma eyes have IOP > 40 mm Hg (Ahmed et al); mean ↑ 8 mm Hg @ 2 hours and ↑ 3 mm Hg @ 24 hours in normal eyes (Thiramalai); mean IOP 31 mm Hg at 4 hours in PXF and POAG eyes (Dietlein); Shingleton, Rosenberg et al – 30% OAG eyes have ↑ IOP on POD #1
      (3.) Etiology - TM collapse in area of incision, pigment or cortical debris, breakdown of blood – aqueous barrier, altered prostaglandin metabolism, toxic damage to TM, viscoelastic effect
      (4.) Must be prepared to treat high-risk eyes with compromised optic nerves – all glaucoma meds potentially useful. Intracameral carbachol effective
   b. Reduced long-term IOP control compared to combined surgery
   c. Future filtration surgery success potentially compromised, especially if conjunctiva violated. Minimal if conjunctiva spared and posterior capsule intact
   d. Cannot depend on beneficial effect of cataract surgery for IOP control – variable: most eyes have long term 1 - 3 mm Hg decrease, but small percentage have ≥ 3 mm Hg rise
   e. Early (30 min – 1 hour) post-operative hypotony may be more frequent than expected (˜ 20% < 5mm Hg – Shingleton, Wadhwani, 5% Shingleton, Rosenberg); Hayashi et al – reduced early hypotony with IOP adjusted at case completion to normal or high IOP
   f. No change diurnal IOP fluctuation (Kim)

3. Indications
   a. Acceptable IOP control on 3 or less medications – assuming absence of allergy problems and no need for systemic CAI
   b. No significant glaucomatous visual field loss or cupping
   c. Higher preop IOP/narrow angles with healthy nerve
   d. Older age
   e. Indications for cataract surgery alone in eyes with glaucoma have increased with appreciation of the IOP-lowering effect of small incision phacoemulsification

E. PHACO “PLUS” -- MIGS: multiple variations

1. Ab interno – no conjunctival incision
   a. Normal pathways: new conduit/opening into Schlemm’s canal (iStent [Samelson et al, Craven et al, Belovay et al], Hydrus, Excimer Laser Sclerostomy/ELT); reopen synchial angle closure (Goniosynechialysis); ablate TM and inner wall of Schlemm’s canal (Trabectome)
   b. Alternate pathways: new conduit into suprachoroidal space (CyPass, Hoch et al); subconjunctival space (AqueSys)
   c. Inflow System: ciliary processes (ECP)

2. Ab externo – no conjunctival incision: inflow system/ciliary processes (Diode Cyclophotocoagulation)

3. Ab externo – small conjunctival incision: alternate pathway via subconjunctival space (InnFocus)

4. Results
   a. IOP reduction slightly more than phaco alone
   b. Reduction in glaucoma medication requirement greater than phaco alone
   c. IOP reduction may be greatest with “bleb” procedures: AqueSys.InnFocus

5. Indications
   a. Reasonable optic nerve
   b. Modest IOP reduction requirement
   c. Reduced medication requirement desired
   d. Multiple stents may have advantage over single stent
e. “Triple Procedure”: phaco/iStent with ECP; phaco/trabectome with ECP

F. COMBINED PHACO and GLAUCOMA SURGERY -- trabeculectomy/canaloplasty/tube shunt – macroincisional glaucoma surgery (“MAGS”)

1. Advantages
   a. Restore vision promptly *
   b. Single procedure *
   c. Reduced glaucoma medication requirements post-op *
   d. Good early post-op IOP control
   e. Better long-term post-op control with phacotrabeculectomy than cataract extraction alone (Friedman et al)
   f. Antimetabolites possible - enhanced success with possibility of more complications
   g. Multiple glaucoma surgical options
   h. Facilitate post-op assessment of optic nerve and visual fields *quality of life

2. Disadvantages
   a. More complications than cataract extraction alone - shallow AC, bleb leak, choroidal effusion/hemorrhage, hypotony, infection, dellen, astigmatism, postoperative myopic shift, tube issues
   b. Longer surgery time than cataract extraction alone
   c. More intensive post-op care requirements than cataract extraction alone – important for patient and surgeon
   d. ? less IOP control than 2-stage procedure?
   e. Glaucoma meds often required post-op
   f. Against-the-rule (ATR) astigmatism – may be exacerbated with larger superior incisions/antimetabolites

3. Indications
   a. More than 3 medications required for good IOP control
   b. Medication use limited by allergy or medical contraindications
   c. Presence of significant glaucomatous visual field loss and cupping.
   d. Age factor - may favor combined procedure for younger patients; cataract surgery alone for older patients.
   e. Presence of other significant risk factors for glaucoma (e.g. pseudoexfoliation, pigment dispersion, angle recession) may favor combined procedure.
   f. Monocular status may favor combined surgery.
   g. Unable to tolerate 2 separate operations
   h. Intracameral triamcinolone results in early decreased inflammation and increased vision in first month (Wang, et al)

G. TWO-STAGE: GLAUCOMA PROCEDURE FIRST, PHACO SECOND

1. Advantages:
   a. Best for immediate IOP control.
   b. ? best for long-term IOP control?
   c. Reduced glaucoma medication requirements post-op
   d. Successful filter/tube eliminates need for miotics – occasionally improves vision post-operatively in patient with cataract
   e. Opportunity for glaucoma enhancement procedure at time of cataract surgery – multiple options

2. Disadvantages:
   a. 2-stages - delayed visual recovery
   b. Subsequent cataract surgery.
      (1.) Lose some IOP control – controversial
      (2.) More challenging in presence of bleb – multiple issues

3. Indications:
   a. Glaucoma immediate threat to vision
   b. Difficult glaucoma where IOL not indicated in acute situation – active uveitis, active NVG
   c. Success with subsequent phaco makes this option reasonable

H. PSEUDOPHAKIC FILTER – see III. G

III. Techniques

A. PHACO ALONE
1. Pre-op
   a. Topical fluoroquinolones, NSAID 3-days pre-op
   b. Dilation – stop miotics one week pre-op, add non-steroidal anti-inflammatory agent with usual dilation
      regimen, especially if pupilloplasty will be required and/or patient on prostaglandin agonists.
      Prostaglandin agonists not routinely stopped
   c. Consider pre-op CAI, beta-blocker or alpha-agonist if post-op IOP spike a concern and tight
      sclerectomy flap closure anticipated.
   d. Consider cessation of anticoagulation drugs in high risk eyes (Coumadin, Plavix, Ticlia)

2. Paracentesis – mandatory for two-handed phaco (coaxial or biaxial MICS) and to facilitate aqueous release for
   ↑ IOP post-op p.r.n.

3. Location - Temporal small incision phacoemulsification approach strongly preferred to minimize conjunctival
   manipulation. If superior, shift superonasal or superotemporal to preserve virgin conjunctiva for future filtration
   surgery, if needed

4. Management of miotic pupils and iris – Special Situation
   a. Miotic pupil = common finding
      1. Long-term miotics
      2. Patient age - older patients often do not dilate as well
      3. Pseudoexfoliation patients often do not dilate as well
      4. Excessive iris manipulation leads to intraoperative miosis.
      5. Poor pre-op dilation regimen
      6. Iridoschisis, anterior segment dysgenesis, non-iatrogenic and iatrogenic trauma
      7. Intraoperative Floppy Iris Syndrome (IFIS)
         a. Flomax (tamsulosin) – selective alpha₁ receptor (specific for alpha₁A receptor) used for BPH in males and
            urinary hesitation in females. Alpha₁ receptor present in dilator smooth muscle of iris
         b. Hytrin (terazosin), Cardura (doxazosin), Uroxatral (alfuzosin), Rapaflo, Saw Palmetto (herbal remedy)
            associated with IFIS. May occur with finasteride (BPH Rx – inhibits Type II-5 reductase; not alpha antagonist).
            May occur with psychotropic drugs with alpha-blocking effect (mianserin – antidepressant), and
            antihypertensives (prazosin, Hylorel, labetalol)
         c. Flomax dosage 0.4 - 0.8 mg po qd. Discontinuing may improve, but NOT eliminate floppy iris. Floppy iris may
            occur with Flomax discontinued 1 or more years before cataract surgery. “Once a Flomax patient, always a Flomax
            patient”
         d. Findings: Poor dilation, floppy iris, iris prolapse, progressive miosis intraop.
            Present in 63% (10/16) in Chang, Campbell initial study; No IFIS 14%, mild 17%, moderate 30%, severe 43% of IFIS
            Study Group (Chang, Osher et al)
         e. Rx to maximize pupil size pre-op in IFIS patients:
            1. Atropine 1% preop
            2. Intracameral epinephrine
               a. 0.1 ml non-preserved epi 1:100,000 in 0.9 ml BSS (Nightingale)
               b. 0.3-0.5 ml non-preserved epi 1:1000 in 3 ml BSS under IFIS. (Masket)
               c. 1.0ml Epi 1:1000 in 4 ml BSS (Chang)
            3. Lidocaine and epinephrine
               a. Intracameral Lidocaine and epinephrine (“Shugarcaine” 9 ml BSS plus with 3 ml 4% preservative-free lidocaine and 4 ml
                   1:1000 bisulfate-free epinephrine)
               b. Intracameral Phenylephrine: 7 drops (0.25 ml) 2.5% preservative-free Phenylephrine added to 1 ml BSS (Packard, Lorente
                  et al)
            4. Iris hooks (diamond configuration) or pupil expansion ring
      f. Phaco techniques
         1. Proper incision construction – long, anterior corneal entry
         2. Soft shell technique with OVDs
         3. Gentle, slow hydrodissection
         4. Healon 5 (repeated injection pm) with low flow parameters and phaco below anterior capsule
         5. Nucleus flip with phaco above iris plane
         6. Avoid infusion directed at iris plane
         7. Consider prechopping under viscoelastic maintenance of the AC prior to introduction of infusion
         8. Biaxial MICS

b. Miotic pupil = demands on technique
   1. Marginal visualization - all steps involving intraocular manipulation become more difficult:
Capsulorhexis – phacoemulsification - IOL implantation

(2.) Two-instrument technique helpful - requires bimanual dexterity
(3.) Skill in endocapsular phacoemulsification techniques (e.g. divide and conquer) helpful
(4.) Iris suturing sometimes indicated

c. Goals in management

(1.) Achieve adequate pupil size (4-5 mm)
(2.) Preserve pupil reactivity
(3.) Preserve normal pupil contour

d. Surgical techniques for management of the miotic pupil

(1.) Avoid excessive iris manipulation
(2.) Epinephrine in BSS infusion bottle
(3.) Strip peripupillary membranes – aspirate pigment on anterior capsule p.r.n.
(4.) Sweep and release synechiae
(5.) Viscoelastic pupil expansion (consider Healon V)
(6.) Bimanual iris stretch without sphincterotomies

(a.) Often eliminates need for scissor sphincterotomies and other techniques
(b.) Slow, steady bimanual stretch to limbal area
(c.) 12 to 6; 9 to 3 meridians – “micro sphincterotomy technique”
(d.) Excellent preservation of pupillary function and contour
(e.) Mechanical pupil dilators (Beher-Moria – 4 point; Keuch – 2 point)
(f.) Avoid if potential IFIS patient
(g.) Effective, fast, cheap

(7.) Self-retaining pupil expanders

(a.) Malyugin Ring (MST – Microsurgical Technology) – foldable polypropylene ring via inserter, thin profile, 4coils hold pupil ≈ 5 mm; 2 sizes
(b.) “Perfect” pupil expansion device (Mivella Ltd., Sydney, Australia) - grooved PMMA ring
(c.) Morcher 5S Pupil Ring (FCI Ophthalmics, MA) – grooved PMMA ring
(d.) Silicone expanders – Graether (Eagle Vision, TN), preloaded, 7-8 mm pupil
(e.) Useful for iridoschisis, floppy iris
(f.) Effective, slower, expensive if no reuse

(8.) Self-retaining iris retractors (Mackool - Titanium- Storz, Akorn Metico reusable; Grieshaber – flexible - 5-0 nylon with adjustable silicone sleeve “reusable”; Synergetics, Chesterfield, MO, flexible nylon, silicone cinch “reusable”; 4-0 polypropylene (Katena, FCI Ophthalmics) – reusable; 6-0 nylon (Alcon) – disposable; micro iris hooks – gold wire, Becton Dickenson – reusable

(a.) 4 paracentesis incisions – proper orientation critical
(b.) Sequential, gradual hook retraction minimizes sphincter tears
(“micro sphincterotomy” technique)
(c.) Relax tension on hooks anterior to keratome incision prior to phaco to decrease iris contract with emulsifier
(d.) Diamond vs. rectangle shape
(e.) Effective, slow, cheap if reusable

(9.) Scissors sphincterotomies

(a.) Multiple (Fine technique)-minisphincterotomies
(1.) 8 or more
(2.) Short cuts
(3.) Long-angled Vannas scissors and right-angled scissors
(4.) Stretch with hook to break fibrotic adhesions
(5.) Good preservation of function and pupillary contour
(6.) Avoid if potential for IFIS
(b.) Few (1-3)
(1.) Short or long
(2.) 1 quadrant: oval configuration
2 quadrants: hammock configuration
(3.) Aid inferior exposure
(4.) Couple with superior sphincterectomy to aid superior exposure
(5.) Beware iris tags - “magnetic” attraction to phaco tip

(10.) Superior sphincterectomy

(a.) Two-instrument technique - tent up iris with hook via paracentesis and cut a small, crescentic superior sphincterectomy with long, angled Vannas scissors via phaco incision
(b.) Aids superior exposure
(c.) Pupillary reactivity preserved with near-normal iris contour

(11.) Keyhole/sector iridectomy

(a.) Maintain sector iridectomy opening for some diabetics/patients with retinal disease – minimizes inflammation and maximizes posterior segment view
(b.) Iris suture—if required
1. 10-0 Prolene or nylon
2. Pre or post-place: tie after IOL implantation
3. Utilize paracentesis to enhance needle passage and exit – guide exit with viscoelastic cannula
4. Form chamber with viscoelastic
5. Ethicon CIF-4, TG-160, STC-6 (straight); Alcon PC7
6. Facilitates restoration of taut iris diaphragm

(12.) Mydriatic sponge – 4x2mm porous plastic polymer placed in inferior fornix 1 hour preop for depot release of mydriatic (IOL Tech Laboratories, LaRochelle, France – phenylephrine, tropicamide); or simple pledge soaked with tropicamide 1%, phenylephrine 2.5%, NSAID, antibiotic, topical anesthetic

(13.) Intraoperative pharmacologic manipulation
(a.) Epinephrine – topical 1:1000, intracameral 1:10,000
(b.) Tissue plasminogen activator (tPA): 5-25 micrograms, 10 micrograms usually sufficient – generally used postoperatively for inflammatory membranes – effect often seen within 10-30 minutes

(14.) Use Second Instrument (e.g. Kuglen hook) to move iris and facilitate exposure for capsulorrhexis and phacoemulsification

(15.) Microscope tilt may enhance visualization - ↑ “visible” diameter of lens

(16.) Intraoperative iris prolapse
(a.) Flaccid iris, posterior entry, excess viscoelastic, floppy iris
(b.) Rx
[1.] Decompress AC, repos iris
[2.] Viscoelastic tamponade
[3.] Iris hooks
[4.] Iridectomy
[5.] Vitreous aspiration, if very shallow AC

5. Capsulorrhexis
a. Keeps iris away from phaco tip in endocapsular techniques
b. Facilitates separation of IOL from the iris - reduces pupillary capture of IOL, posterior migration of iris and pigment dispersion
c. Strive for size of 5-5½ mm – good for in-the-bag IOL implantation and/or optic capture
d. Capsulorrhexis can be enlarged after IOL implantation
e. Small capsulorrhexis (particularly in pseudoexfoliation eyes) may predispose to anterior capsular contraction and phimosis. This is easily treated by making relaxing incisions in the anterior capsular ring with the YAG laser post-operatively – best done early to avoid IOL displacement. Vacuum epithelial cells from underside of anterior capsule to reduce incidence of phimosis
f. Critical for effective, safe phacoemulsification

6. Phacoemulsification - points to assist small pupil phaco
a. Two-instrument technique
b. Hydrodissection – CRITICAL -- strive for free nucleus rotation within the bag. Hydrodelineation helpful
c. Stop and chop variations – groove, crack, hemiaspiration or chop/aspiration; or phaco chop; or nucleus flip technique
(1.) Vary vacuum, flow, power - utilize advantages of newest generation phaco equipment
(a.) Divide and conquer
[1.] Groove - low vacuum, low flow, linear power
[2.] Heminucleus aspiration / chop/aspiration – high vacuum, moderate flow, linear power
[3.] Epinucleus - moderate vacuum, high flow, low power
[4.] Nucleus flip – phaco tip vacuum purchase of nucleus and second instrument protect against excess AC turbulence
[5.] Assure complete crack so that nucleus can be pulled to central position within capsular bag for chop or hemiaspiration without having to extend under iris or to capsular equator

Pseudoexfoliation weak zonules – Special Situation
(see Singleton, Crandall, Ahmed JCRS Review Article: Pseudoexfoliation and the Anterior Segment Surgeon)
1.) Shingleton, Heltzer and O’Donoghue – 300+ eyes without PXE: NO zonule dehiscence or capsule tears; 300+ PXE eyes: 2.5% zonule dehiscence, no capsule tears. Hyams et al – PXE (137) = normal (136) but complication rate 4-5.8%

2.) Shingleton, Marvin – 1000+ eyes with PXF: 2.5% zonule dehiscence – overall 1% if no pre-op / intra-op clues of zonule weakness; 50% if zonule weakness in fellow eye or phacodonesis

3.) Aravind: PXF 0.9% zonulysis, no PXF 0.5% zonulysis (ARVO 2012); Ophthalmic Surgical Outcomes Project: PXF similar to control if pupil expansion devices and capsule rings used prn in PXF group (AAO 2013)

4.) Clues to zonule problems:
   (a.) Pre-op clues: History of zonular weakness in fellow eye. Slit Lamp Exam: AC depth symmetry, phacodonesis – pan or focal, visibility of lens equator on eccentric gaze, decentered nucleus on primary gaze, iridolenticular gap, changes in contour of lens periphery; less than 2.5 corneal thickness axial depth
   (b.) Intra-op clues: “pseudo elastic capsule”, AC depth instability, limited nucleus rotation, excessive lens position shift (A-P) direction, tilt, difficult nucleus rotation, difficult cortex removal with capsule striae

5.) Intra-operative surgical techniques
   (a.) Incision location superotemporal, consider scleral flap or posterior limbal incision
   (b.) Capsulorrhexis – size: 5.5 mm ideal; assess zonules, use capsule retractors or capsular stabilization device to support rhexis p.r.n. (see below); needs to be intact for CTR use
   (c.) Good hydrosuction and hydrolinulation is critical
   (d.) Phaco – avoid downward pressure on nucleus; use bimanual rotation and chop techniques. Free nucleus rotation important. Decrease infusion bottle height – avoid over expansion of AC. Consider viscodissection of nucleus and prechop
   (e.) Consider capsule retractors, capsule tension ring (CTR) or capsule retaining segment (CTS): Mechanism – distribute centrifugal force circumferentially to oppose capsule constriction and zonule separation
   [1.] Capsule retractors (Mackool, MST, Yahuchi-Kazawa) – use immediately after or concurrent with capsulorrhexis. Supports lens in A-P direction and provides rotational support. Avoid stretching rhexis and lid/lid retractor contact
   [2.] CTR – non suture (Morcher, Ophtec) – generally used after phaco/IA. Good for mild zonule weakness or segmental zonule problem up to 180°. Late IOL decentration still possible with this type CTR. Insert with forceps or inserter; insert late as possible (Ahmed) – if before phaco (Fine), viscodissect cortex first and guide placement with hook in 2nd hand. Early placement facilitates phaco, but may be associated with extension of zonular dialysis. Late placement may be safer regarding dialysis extension, but requires capsule retractors or CTS for support during phaco. Can be sutured intra-operatively or later if IOL decentration
   [3.] CTR – sutured: modified Cionni Ring – generally used after phaco/IA. Good for all types of zonule weakness; resistant to late IOL decentration
   [4.] CTS – Ahmed. Can be used before phaco/IA. Good for all types of zonule weakness; resistant to late IOL decentration. Temporary or permanent
   (f.) Consider I/A after IOL/ring implanted – use tangential traction of cortex rather than centripetal – strip toward area of zonule weakness, not away. Henderson CTR facilitates cortex removal. Vacuum subcapsular epithelial cells
   (g.) Questionable effect of CTR on postop refraction and IOL position
   (h.) IOL – acrylic or new generation silicone IOL can be used in the bag, if intact zonules; consider large optic, all-PMMMA IOL with haptics in axis of weak zonules and/or haptic suture fixation if weak zonules. Foldable IOL with Prolene haptics in sulcus and optic capture within capsulorrhexis: good for weak zonules. AC IOL always an option. Avoid plate haptic style PC IOL
   (i.) Be prepared for vitrectomy; posterior segment surgeon back-up availability in high risk cases

6.) Post-op: beware of capsule contraction and IOL displacement.
   (a.) Capsule contraction – anterior capsule phimosis
   [1.] May be reduced with larger capsulorrhexis, CTR, three-piece acrylic lenses, removal of anterior subcapsular lens epithelial cells
   [2.] Consider capsule relaxing incisions (2) at time of surgery
   [3.] Early YAG laser treatment
   (b.) IOL decentration/dislocation
   [1.] All IOL types
   [2.] Jehan et al, Shingleton et al – mean 8½ years after phaco
[3.] Prevention
[a.] Surgical issue – utilize CTR or sulcus fixation with IOL capture in high risk cases, avoid plate haptic PC IOLs
[b.] YAG laser for anterior capsule contraction early, if it occurs

[4.] Treatment
[a.] Suture fixation – lasso suture, 9-0 Prolene, 8-0 Goretex
[b.] IOL exchange with AC or sutured PC IOL (iris or sulcus)

e. Crowded anterior chamber – Special Situation (high hyperopia, nanophthalmos, CACG)

(1.) Associated findings (R. Brown)
(a.) Deep set eye, small orbit
(b.) Tight lids
(c.) High lens/eye volume ratio
(d.) Small cornea
(e.) Miotic, fixed pupil
(f.) Thick sclera

(2.) Pre-op Treatment
(a.) Small volume anesthetic block with compression
(b.) Consider mannitol pre-op

(3.) Intraoperative techniques
(a.) Anterior entry via temporal, clear cornea- avoid iris prolapse
(b.) Healon 5 – flatten iris
(c.) Beware capsulorrhexis tear running peripherally – “round” lens
(d.) PP vitrectomy p.r.n. via single port to achieve satisfactory deepening – no infusion Required, “dry vitrectomy”
(e.) Iris/capsule retractors p.r.n.
(f.) Goniosynechialysis p.r.n.
(g.) Piggyback IOL – accurate calculation (Holladay 2, Hoffer Q) Small chance of ILO – Inter-lenticular Opacification (membrane). Favor 2 silicone lenses (without square edges) or 2 PMMA lenses

(4.) Post-op – beware aqueous misdirection

f. Angle closure glaucoma – Special Situation

(1.) IOP reduction with phaco greater in eyes with 1% ACG vs. OAG
(2.) Effective IOP reduction in Acute ACG with primary phaco/IOL – Jacobi et al: ↓ IOP, ↑ vision with primary phaco; conventional surgical iridectomy ↓ IOP but associated with multiple surgical interventions confirmed by Lam, 2008
(3.) Imaizumi et al: ↓ IOP in Japanese population with phaco in ACG and previous ACG treated with LI. Cataract surgery may open the angle and ↓ IOP in eyes with nonysynchial residual angle closure after LI (Nonaka)
(4.) Phaco alone deepens chamber greater than phaco trab in PACG eyes (Tham)
(5.) Phaco alone provides better short-term IOP control in eyes with acute ACG than chronic ACG with PAS greater than 180° (Zhuo)
(6.) Phacotrabeculectomy provides greater IOP reduction (with more post-op complications) in eyes with chronic ACG than phaco alone; no difference in glaucoma progression. (Tham, et al)
(7.) Capability of coupling intraoperative goniosynechialysis with phacoemulsification in acute, subacute and chronic angle closure situations (Shingleton, Chang et al; Harasymowycz et al)

7. IOL
a. Any size, type implant possible
(1.) Foldable IOL - reduced incision size, inflammation
(a.) Uveal biocompatibility
   Deposits may occur on silicone, acrylic and PMMA lenses- variable reports on incidence—may be lowest with acrylic, second generation silicone lenses
(b.) Capsule compatibility: Incidence of anterior capsule contraction and PC opacification may be higher in silicone lenses. IOP reduction similar for silicone and acrylic
(2.) Large optic IOL - best with non-sutured large pupil or sector iridectomy
(3.) IOP increases to 60 mm Hg (mean peak IOP) during implantation (Kamae)

b. Beware of zonule weakness in pseudoexfoliation eyes - may dictate type of IOL
c. PC IOL in capsular bag = implant of choice. Reduce pigment dispersion. Pigment dispersion and ↑ IOP reported with one-piece acrylic IOL in sulcus or prolapsing through large, eccentric capsulorrhexis
d. Current generation tripod or quadrupod AC IOL satisfactory if angle status not anatomically compromised by PAS, recession or clefts (See Donaldson et al). Avoid AC IOL if such circumstances exist
e. Consider sutured PC IOL with sulcus/glued scleral flap fixation or iris fixation in cases of inadequate capsular support and/or anatomic angle compromise
f. Premium IOL – see III. A.14

8. Assess pupil after IOL implantation
a. Intra-op carbachol (MioStat) may induce greater miosis than acetylcholine (Miochol) and helpful to bring iris over IOL; may also enhance post-op IOP control. Not routinely required
b. Manipulate iris - stroke iris back over IOL from dilated position.
c. Suture iris p.r.n.
d. Remove viscoelastic after iris suturing, aspirate pigment or blood debris that may lead to posterior synechiae

9. Intraoperative measures to enhance IOP control
a. IOP > 60 mm Hg during phaco (coaxial and MICS) – highest during hydrodissection, viscoelastic injection, IOL implantation (Khng et al).
b. Consider lower viscosity viscoelastic with effective removal
c. Consider anterior chamber maintainer rather than viscoelastic for IOL implantation (Shingleton, Mitrev et al)
d. Intracameral miotic – carbachol effective

a. Monitor IOP closely: 30 minutes to 24 hours; IOP may be low at 30 minutes (up to as high as 20%) and 2-7 hours may be most critical time for high IOP – correlates with higher IOP on POD #1
b. Consider pre-op and post-op CAI, beta-blocker, alpha-agonist, miotic. Combination therapy with aqueous suppressants may be more effective. Intracameral carbachol may be most effective. Others suggest aqueous outflow enhancing agents may be best. Treated eyes have lower IOP on POD #1 than non-treated eyes. Questionable effect for prostaglandin agonist
c. Avoid injection of long acting steroid – beware of steroid response
d. Release aqueous via paracentesis p.r.n. if significant IOP elevation Effect may be transient: Hildebrand et al – 11 healthy eyes IOP > 40mg 4-6 hr post-op; para-release to 5mm Hg → mean 38.5mm Hg at 60 minutes. Beware “inverse Seidel” after decompression and ingress of surface fluid into eye (Chawdhary)
e. ↑ preoperative IOP, diagnosis of glaucoma or ocular hypertension, younger age, preop wide angle opening, myopia, acrylic IOL correlates with ↑ IOP on POD #1 (Slabaugh)
f. Topical steroids, NSAIDs (Levkovitch-Verbin et al: equal success)

11. Post-op Medical Rx: Stop glaucoma medications if IOP satisfactory. Resumption of glaucoma medications post-op based on IOP/disc/VF. If meds required, favor following order: aqueous suppressants, alpha-agonists, prostaglandin agonists, miotics. Prostaglandin agonists unlikely to exacerbate CME, if uncomplicated surgery

12. Phaco effect on CME- no difference between phaco in glaucoma and non-glaucoma patients, if no surgical complications. Increased CME if rupture of posterior capsule and vitrectomy required (Law). Prostaglandin agonists unlikely to increase incidence of CME if no complication and pre-op/post-op NSAIDs utilized

13. IOP results at 1 - 5 years – 1-3 mmHg decrease: normal and glaucoma suspect patients. Reduced medication requirements in glaucoma patients initially with increased need over time. Indications for small incision phacoemulsification has expanded in glaucoma patients because of these results.

14. Glaucoma and Astigmatism Correction / Premium IOL's.
   a. Corneal relaxing incisions not contraindicated, pending ocular surface/bleb issues
   b. Toric Aspheric –
      (1.) Stable astigmatism and IOP (not too low) – excellent choice.
      (2.) Toric IOL concurrent or following trabeculectomy (Grover et al):
      (3.) If PXF or, likely future filter – Toric IOL relatively contraindicated – prefer AK
   c. Presbyopic IOLs
      (1.) Challenge for glaucoma patient.
         (a.) Optic neuropathy.
         (b.) Zonulopathy
         (c.) Pupillopathy
         (d.) Maculopathy
         (e.) Keratopathy
         (f.) Sociopathy – unrealistic expectations
      (2.) Contrast sensitivity
         (a.) ↓ in glaucoma
         (b.) Functional impact: driving, night vision
         (c.) MF IOL - ↓ CS
      (3.) Anatomic and Structural changes impact both MF and Accommodative IOL’s
(a.) Pupil 
(b.) Zonules 
(c.) Filter /bleb effect- low IOP, astigmatism

(4.) MF IOL / accommodating IOLs possible: balance between glaucoma damage visual needs – patient expectations. Caution advised. Avoid in PXF patients

B. PHACO/MIGS

1. Multiple variations – See II. E.
2. U.S. Approved
   a. Glaukos iStent 
   b. Trabectome 
   c. ECP – See III. E. 3.

C. COMBINED PHACO AND TRABECULECTOMY SURGERY (“MAGS”) - via separate incisions

1. Separation of phaco and trabeculectomy components to different sites felt by some ophthalmologists to enhance development of effective filtration. Permits phacoemulsification from a position most comfortable for cataract surgeons. Simple, safe, effective procedure; longer than combined surgery via single incision.
2. Phacoemulsification/IOL component - performed first
   a. Temporal approach 
   b. Clear cornea/limbal approach - minimize conjunctival manipulation 
   c. Small incision: foldable IOL preferred 
   d. Consider buried 10-0 nylon suture closure to facilitate early digital pressure, if needed, in post-op phase. 
   e. Standard phacoemulsification and IOL implantation
3. Trabeculectomy component - performed second 
   a. Superior 
   b. Conjunctival flap of surgeon preference 
   c. Antimetabolite, if indicated 
   d. Standard trabeculectomy 
   e. Peripheral iridectomy may not be required with combined procedures unless iris prolapse through sclerectomy. Rendering patient pseudophakic usually deepens anterior chamber and angle inlet. Problems associated with bleeding from iridectomy may be greater than risk of pupillary block or sclerectomy obstruction, in absence of iridectomy. IOP control and bleb development equal between PI and no PI groups in randomized series (Shingleton, Chaudhry et al)
4. Results
   a. Equivalent to better IOP control than single-site procedure and may require less glaucoma meds (Jampel/Friedman – evidence based review); no significant difference compared to single-site. (Gdh et al – Meta-analysis). 
   b. Shingleton, Price et al – equal IOP reduction, visual improvement and medication reduction between single-site vs. separate site group. 
   c. Buys (AGS 2007): Equal IOP reduction; lower endothelial cell count in separate site group. 
   d. Small amount WTR astigmatism induced. Good for ATR astigmatism 
   e. Surgeon preference

D. COMBINED PHACO AND TRABECULECTOMY SURGERY (“MAGS”) - via single incision

1. Single incision approach is simple, safe, fast and effective; potentially less comfortable for temporal phaco surgeon.
2. Choose your best operation - minimize manipulation, be atraumatic to tissues.
3. Pre-op
   a. Beware allergic conjunctival changes: follicular, inflammatory changes (brimonidine, topical CAI, dipivefrin, BAK) - treat with cessation of offending agent and topical steroids.
   b. Beware hyperemic conjunctival changes: red, injection non-inflammatory changes (prostaglandins, epinephrine agonists, BAK) – treat with cessation of offending agent and topical steroids pre-op.
   c. Topical fluoroquinolone, NSAID 3 days; stop miotic 1 week. Dilation – Add topical NSAID to usual dilation program.
   d. Consider pre-op CAI, beta-blocker or alpha-agonist if post-op IOP spike a concern and tight sclerectomy flap closure anticipated.
   e. Topical anesthesia not contraindicated.
   f. Consider cessation of anticoagulation drugs in high risk eyes (Courmadin, Plavix, Ticlid).
4. Paracentesis - mandatory for testing filter outflow and two-handed phaco.
5. **Location - superior:** minimize size of incision to spare virgin conjunctiva for repeat filtration surgery if needed. Phaco with small incision IOL an advantage - minimizes violation of conjunctiva. Use positioning suture p.r.n. – helpful with limbal-based flap.

6. **Conjunctival flap - minimize manipulation,** use non-toothed forceps and cellulose sponges for flap retraction, and maintain meticulous **hemostasis** (underwater unipolar diathermy).
   a. Both limbal-based and fornix-based conjunctival flaps effective for ↓ IOP, bleb development, vision, ↓ glaucoma medications (Shingleton, Chaudhry).
   b. Limbal-based flap: reduced bleb leaks; permits earlier laser suture lysis (LSL), earlier digital pressure, earlier 5-FU. More tedious than fornix-based, requiring more time and may be associated with higher rate of encapsulated blebs/anterior, localized blebs
      1. High incision - > 10 mm posterior to limbus
      3. Carry dissection to anterior reflection of conjunctiva. Utilize #15 Bard-Parker blade, Tooke knife or iris spatula p.r.n.
   c. Fornix-based flap – particularly useful approach for scarred conjunctiva. Faster than limbal-based, but more anterior leaks which can compromise bleb development, if not identified and treated
      1. Two basic techniques
         a. Anterior dissection at anterior insertion of conjunctiva
         b. Retain limbal remnant (1-2mm) with vessels
      2. Extent of dissection based on mobility of conjunctiva. Wider flap with more extensive scarring. Side-relaxing incision possible.
      3. Episceral stay suture may be placed after conjunctival flap is mobilized in order to retract conjunctiva and facilitate exposure.
   d. Tenon's fascia
      1. Excise only if exuberant - black patients, young patients, inflamed eyes. Minimize excision if Intraoperative antimetabolite utilized.
      2. Search for plane just above episcleral vessels in order to minimize bleeding when excising Tenon's fascia.

7. **Antimetabolite application**
   a. Mitomycin
      1. Antibiotic derivative of Streptomyces caesipitosus
      2. Selectively inhibits DNA replication by inhibiting mitosis and protein synthesis
      3. Inhibits fibroblast proliferation. Effect localized to treated area – 125 x more potent than 5-FU
      4. Topical intraoperative application prior to AC entry under conjunctiva
      5. Technique
         a. Dosage 0.2 - 0.5 mg/ml; Mitosol (0.2%) FDA approved
         b. Vehicle: cut cellulose sponge or gel foam - approximate saturated size 3 x 6 mm; broader zone of application advantageous – use multiple pledgets; or inject subconjunctivally
         c. Duration of application: 1 - 5 minutes, trend toward shorter application time
         d. Keep cut edge of conjunctiva away from mitomycin-soaked pledget
         e. Contact sclera and subconjunctival tissue; ? under scleral flap
         f. Copious irrigation
      6. Results: lower IOP and more complications if mitomycin used (Jampel/Friedman – evidence based review)
      7. Topical use on conjunctiva and injection (being used more frequently) remain investigational
      8. Mitomycin may be refrigerated or frozen to preserve potency
      9. Mitomycin may retard rate of posterior capsule opacification
   b. Topical 5-fluorouracil (5-FU) is an alternative: 50 mg/ml, 5-minute duration - ? effect per Jampel/Friedman; 31% IOP reduction (Chang)
   c. Bevacizumab (Avastin) – intravitreal subconjunctival
   d. Ologen Collagen Matrix (Optous) – biodegradable scaffolding matrix
   e. Surodex (60 micrograms dexamethasone) pellet drug delivery system placed intrascleral. Moderate ↓ IOP, less complications than intraop 5-FU (Seah).

8. **Scleral flap, AC entry and sclerectomy**
   a. Any shape flap (triangular, rectangular or house-shaped) - mobilize anteriorly into clear cornea
   b. 1/2 scleral thickness
   c. Base of flap equals size required for IOL implantation
   d. AC entry: anterior; size >2 mm to permit punch entry: ExPress – 25-27 gauge needle
   e. Sclerectomy: Kelly Descemet's punch, Khaw (smaller), Crouzafon (larger); Size – 1x2 mm, 0.5 mm adequate
   f. 10-0 nylon suture closure, bury knots - longer suture pass facilitates LSL
g. Tightness of closure-strive for slow, spontaneous flow under flap with maintenance of anterior chamber.

h. Tighter flap closure in eyes at higher risk for post-op bleeding

i. Consider horizontal mattress flap compression suture (Palmberg, Johnstone) with or without scleral patch graft to reduce risk of hypotony in antimetabolite-enhanced combined procedures.

j. Some surgeons shift suture placement to elevate central zone of rectangular flap with or without wick - facilitate aqueous egress.

k. Scleral flap can be modified: conventional trabeculectomy flap – conventional phaco scleral tunnel with stitch or no stitch – modified scleral tunnel with relaxing incision.

1. Goal - best IOP: theoretically change trabeculectomy component as little as possible from conventional filter procedure
   (a.) Conventional trabeculectomy flap - triangle or rectangle
   (b.) Advantages: all advantages of standard filtration procedure: laser suture lysis (LSL) or releasable suture, digital massage
   (c.) Disadvantages
      [1.] Limbal based scleral flap architecture predisposed to ATR astigmatism drift
      [2.] Radial suture: ↑ astigmatism
      [3.] Delay visual recovery

2. Goal - fastest attainment of best vision: theoretically change phaco component as little as possible from standard scleral tunnel cataract procedure
   (a.) Conventional scleral tunnel - "no-stitch" combined procedure
   (b.) Advantages: all advantages of standard no-stitch scleral tunnel phaco procedure
   (c.) Disadvantages
      [1.] Variable post-op IOP control – more problems with ↑ IOP and shallow AC
      [2.] Lack LSL or releasable suture capability to titrate flow through scleral flap post-operatively

3. Hybrid – modified scleral tunnel/trabeculectomy flap: scleral tunnel with central "T"-relaxing incision
   (a.) Goal – theoretically combine best of both traditional trabeculectomy flaps and scleral tunnel architecture
   (b.) Technique (Shingleton and Kalina)
      [1.] Standard scleral tunnel - located 2 mm posterior to Tenons insertion, AC entry 1 mm anterior to Tenons insertion in clear cornea; 3 x 3 mm tunnel created
      [2.] Standard phaco/IOL procedure
      [3.] Central "T" relaxing incision in scleral flap 1.5 mm in length
      [4.] Punch sclerectomy: 1-mm posterior x 2-mm horizontal
      [5.] 10-0 nylon horizontal mattress suture: bisect "T" relaxing incision (0.75 mm from groove) suture placement: bed-flap-flap
      [6.] Temporarily tie suture - single, 2-loop, reverse throw - cinch tightly under scleral flap
      [7.] Deepen AC with BSS via paracentesis: cinch knot will loosen to tension that permits egress of BSS under flap
      [8.] Permanently tie 10-0 nylon suture at above tension (buried)
      [9.] Close conjunctiva: limbal or fornix-based flap

   (c.) Advantages
      [1.] Stable architecture of standard phaco scleral tunnel incision - anchored posteriorly (rather than at limbus) to minimize ATR astigmatism drift and maximize rate of vision recovery. Central "T" relaxing incision converts tunnel to "frown-like" configuration
      [2.] Central "T" relaxing incision improves aqueous egress over standard scleral tunnel and facilitates bleb development
      [3.] Horizontal mattress closure minimizes early post-op hypotony and shallow AC and maximizes post-op control of IOP and bleb development via LSL. It also avoids induced astigmatism of radial sutures.

   (d.) Disadvantages - single suture for LSL, slightly more anteriorly directed aqueous egress
   (e.) Stable wound architecture with this technique results in predictable mild ATR astigmatism effect. This facilitates simultaneous use of corneal relaxing incisions to modify astigmatism intraoperatively, if indicated

k. Releasable sutures
   (1.) Multiple techniques – all effective in reducing post-operative hypotony (Cohen, Wilson, Johnstone and others)
   (2.) Timing of release similar to laser suture lysis
   (3.) Longer procedure
   (4.) Astigmatism issues
9. Peripheral iridectomy: may not be required with combined procedures unless iris prolapse through sclerectomy. Rendering patient pseudoephakic usually deepens AC and angle inlet. Bleeding from iridectomy or sclerectomy obstruction may be greater problem than risk of pupillary block or sclerectomy obstruction, in absence of iridectomy. IOP control and bleb development equal between PI and no PI groups in randomized series (Shingleton, Chaudhry et al).

10. Conjunctival closure – utilize non-toothed forceps, protect tissues from excessive trauma
   a. Limbal
      (1.) Suture: 9-0 Vicryl (Ethicon BV-100), 10-0 nylon (BV-75); thin wire, taper, vascular needle
      (2.) Closure techniques
         (a.) One or two interrupted sutures: Conjunctiva-Tenon's-Conjunctiva. Anchor suture line superiorly. Complete closure with running, locking suture; conjunctiva-conjunctiva
         (b.) Layered closure favored by some
   b. Fornix
      (1.) Sutures
         (a.) 10-0 nylon, regular needle: wing suture closure
         (b.) 9-0 nylon (Ethicon VAS 100) or 9-0, 10-0 Vicryl - standard limbal remnant running suture closure
         (c.) 9-0 nylon (Ethicon 2890 ;VAS-100 needle): Wise fornix-flap closure
      (2.) For wing sutures: denude limbal corneal epithelium light cautery; Strive for broad apposition of conjunctiva to cornea well anterior to scleral flap. Single, imbricating wing suture often adequate. Advantage – minimize sutures near sclerectomy area to minimize inflammation; Disadvantage – wound leaks, anterior bleb migration
      (3.) For running sutures utilizing limbal remnant: first bite at inner edge of posterior conjunctival border. Suture tied to itself, then running suture utilizing horizontal mattress technique. Confirm adequate tension. Advantage – reduce bleb leaks and anterior migration of bleb; Disadvantage – suture near sclerectomy may increase inflammation
      (4.) Wise closure (see reference) – good for scarred conjunctiva

11. Test filtration and bleb elevation via paracentesis at completion of procedure. Utilize topical 2% fluorescein to test for leaks

12. Cataract and glaucoma plus refractive surgery: corneal relaxing incisions intra-op or post-op possible if surgeon documents stable scleral mobilization technique (See III, C j). Caution indicated
   a. Shingleton "T"-relaxing incision - stable architecture
   b. Mitomycin with rectangular scleral flaps with tight 10-0 nylon suture closure may be associated with initial WTR astigmatism and later ATR drifts
   c. Axial length may rarely decrease after combined surgery, especially if hypotony develops or high IOP existed prior to surgery

13. Results: Combined Surgery – Single Incision
   a. Shingleton, Kalina 1995 – no mitomycin with 1 year follow up: ↓ mean IOP 5 mm Hg, ↓ glaucoma medication requirements > 75%
   b. IOP reduction sustained at 3 years; increased medication requirements
   c. Phacotrabeculectomy with mitomycin (Jin, Crandall): ↓ mean IOP 8 mm Hg at 30 months post op with ↓ meds
   d. Phacoetrabeculectomy IOP and GMR ↓ greater in ACG vs OAG (Rao et al)

E. COMBINED PHACO AND OTHER GLAUCOMA SURGERY - utilizing other types of glaucoma procedures

1. Express mini-glaucome shunt – under flap; shunt to site near limbus, create bleb equivalent to filter

2. Deep sclerectomy procedures
   a. Viscocanalostomy (Stegman); Park et al 4.3 mmHg IOP ↓ at 1 year. 3.6 mmHg IOP ↓ at 2 years, better than phaco alone. Shoji 3 mmHg ↓ IOP at 2 years in NTG eyes, better than phaco alone. Kobayashi: mitomycin phacotrabeceuclectomy results equal to phacoviscocanalostomy at 1 year
   b. Canaloplasty with Schlemm's canal tension suture: mean IOP reduction 8 mmHg at 1 and 3 years; significant ↓ glaucoma medication . Requirement GMR (Shingleton et al; Ayyala et al); phacocanaloplasty may be more effective than canaloplasty in phakic eyes
   c. Wick procedures with collagen wick (aquawick), hyaluronic acid implant (Sourdille, lens capsule (Answar et al), or sclera. With or without antimetabolite

3. Tube/shunt to site remote from limbus (e.g. Molteno, Baerveldt, Ahmed, Krupin) -- all types possible

4. Ciliary body endophotocoagulation (ECP) - Uram and others; beware chronic inflammation postop characteristic of all external cycloablative therapies; such inflammation appears to be much less with ECP
a. Equipment
   (1.) Console
      (a.) Light: 175 watt XENON
      (b.) Image: view on video monitor, not via microscope
      (c.) Laser: 810-semiconductor diode
   (2.) Laser endoscope: 20 gauge, curved / straight
   (3.) Power comparisons (R. Feldman):
      TS EPC noncontact - 240 joules
      TS EPC contact - 147 joules
      TS Diode - 96 joules
      ECP - 16 joules
      ALT - 8 joules
      SLT - 0.08 joules

b. Technique
   (1.) Standard phaco - clear cornea or scleral tunnel
   (2.) Viscoelastic - AC, PC
   (3.) ECP
      (a.) Direct visualization of ciliary process (CP)
      (b.) Titrate energy delivery with foot pedal
      (c.) Effect proportional to time and distance from CP
      (d.) Strive for whitening, shrinkage of entire CP. No popping or bubbles
      (e.) 180°_minimum treatment; 270° best
   (4.) Remove viscoelastic
   (5.) Beware postop IOP rise

c. Results
   (1.) Uram, Gayton, Alvarado, Lima report excellent result; Berke modest IOP reduction
   (2.) Berke et al (AAO, 2006): 626 eyes, mean t/u 3 years –
      Phaco ECP: ↓ IOP 3 mmHg; ↓ meds 50%
      Phaco alone: no ↓ IOP, no ↓ meds
   (3.) Phaco ECP group: IOP reduction = 2 mm Hg (1.8 phaco alone); 80% ↓ meds (14%); 54% no meds (10%)
   (4.) No chronic inflammation, ↑ CME or phthisis
   (5.) Best IOP lowering via pars plana route with additional row of treatment at pars plana / base of CPs

d. ECP - Pro: simple, no bleb, ↓ meds, rapid recovery; ECP - Con: special equipment – expensive; not indicated in advanced glaucoma only mild ↓ IOP

5. Trabeculotomy – Grover, Feldman, Gimbel, Neuhan, McPherson and others

6. Historical Interest
   a. Brown deep sclerectomy with Eye Pass bi-directional glaucoma tube shunt
   b. Endoscopic erbium: YAG laser goniopuncture (Feltgen et al) 30% IOP at 1 and 3 years with ↓ medication requirements
   c. Ab interno quadrantric trabeculectomy
   d. Clear cornea technique – reverse-hinge trabeculectomy (Langerman)
   e. Holmium laser sclerostomy – Terry and others
   f. Cyclodialysis – Montgomery and Gills, Shields and Simmons; used in ICCE, ECCE eras
   g. Trabeculectomy with internal tube shunt into suprachoroidal space

F. TWO-STAGE: GLAUCOMA PROCEDURE FIRST, PHACO SECOND

1. Filter first
   a. Superonasal – permits easier access for subsequent cataract operation
   b. Favor antimetabolite-enhanced trabeculectomy – less compromise with subsequent cataract operation, cataract progression not a concern
   c. Tube-shunt procedures (e.g. Molteno, or Ahmed) or other non-filtering glaucoma procedure not excluded
   d. AGIS Study: trabeculectomy increased risk of cataract formation by 78% (higher if increased inflammation or flat anterior chamber)
   e. Evidence based review (Hylton et al): glaucoma surgery strongly associated with increased incidence and progression of cataract
   f. 24% rate of cataract extraction after trabeculectomy in young patients (mean 43.7 yrs), mean time 26 months (Adelman et al)

2. Phaco second
   a. Same considerations as phaco alone. Beware low endothelial cell counts
   b. Timing – as long as possible after glaucoma surgery, preferably 3-6 months
c. No Honan balloon or external compression
d. Careful attention to AC depth and infusion bottle height in presence of filtering bleb
e. Do not touch good functioning bleb – consider viscoelastic on and in bleb for protection
f. Location
   1. Temporal-inferotemporal (90 degrees away from bleb) favored - incision greatest distance from bleb; easy access for phaco; clear cornea or scleral tunnel incision technique. Clear cornea approach is associated with less conjunctival inflammation and bleeding. Phacoemulsification and IOL implantation performed as with any temporal approach
   2. Clear cornea adjacent to bleb (superior)
   3. Anterior to bleb (clear cornea) – no conjunctival manipulation; anterior incision – more difficult phaco and nuclear expression; may increase astigmatism
g. No PI required – already present with filter post-op
h. Wound closure – suture closure may permit earlier digital pressure post-op
i. Confirm sclerectomy patency and bleb elevation at end of case. Internal/external revision of bleb possible, if obstruction present
j. Topical mitomycin application to bleb or subconjunctival 5-FU at time of cataract surgery possible
k. Post-op
   1. Vigorous topical steroids, NSAIDS
   2. 5-FU supplementation prn
   3. Bleb needling with or without 5-FU, mitomycin
   4. Tissue Plasminogen Activator (TPA, Alteplase, “cathflo” by Genetec) may be helpful to revive blebs in early post-operative phase (< 2 weeks) – 10-25 micrograms (intracameral) in absence of AC bleeding

3. Results
   a. 58 eyes – improved vision, slight ↑ mean IOP (1.9 mmHg), stable glaucoma medication requirements at 1 year post-phaco. Clear cornea and scleral tunnel temporal approaches – equivalent results. Mitomycin filter versus no mitomycin – equivalent results. Final IOP change ~ 12mmHg → 14mmHg at 1 year (Singleton, Hall, O’Donoghue)
b. Factors associated with ↑ bleb compromise – pre-op IOP >10, ↑ iris manipulation, age <50, post-op OP spike, pre-existing uveitis, cataract surgery within 6 months of filter (Chen et al, 1998; Rebolloida/Munoz-Negrete, 2002; Husain et al, 2012)
c. Refractive outcome – reasonably predictable. Lower pre-phaco IOP correlates with myopic shift in final refraction (Muallem, et al) Greater refractive difference than in control eyes without prior trabeculectomy

4. Decision making for cataract surgery in the presence of a filtering bleb
   a. IOP too high: consider –
      1. Adding internal/external revision at time of clear-cornea phaco with or without antimetabolite supplementation
      2. Refilter at new site
      3. Tube/shunt
      4. ECP/external diode
      5. Other nonfilter glaucoma surgery procedures (MIGS) – decisions based on bleb-conjunctiva status
   b. IOP okay: vigorous topical steroids to minimize inflammation; consider 5-FU post-op; watch for IOP spike post-op
   c. IOP too low (hypotony):
      1. Certain aspects of phaco more difficult
         a. Paracentesis
         b. Capsulorrhexis
         c. Corneal striae
         d. Nuclear cracking
      2. Techniques to consider
         a. Viscoelastic use
         b. Diamond knives
         c. Proper incision size
         d. Chop vs. crack vs. flip
      3. IOL power calculation: issue of axial length
         a. Hypotonous eye results in shorter eye (up to 3 mm) than normal state/fellow eye
         b. Cataract surgery leads to increased IOP resulting in increased axial length—usually still shorter than pre-filter, normal IOP, axial length
         c. Base IOL calculation on axial length approximately midway between presumed pre-hypotony and actual hypotony axial lengths
         d. Immersion ultrasound measurements most accurate
      4. IOP elevation after cataract surgery alone may be enough to reduce maculopathy changes. Autologous blood injection may also be considered at time of phaco to limit bleb function
      5. Bleb revision/pericardium graft/Palmberg suture p.r.n.
G. **GLAUCOMA OPERATION IN PSEUDOPHAKIC EYE: PHACO FIRST, GLAUCOMA OPERATION SECOND**

1. Conjunctiva, capsule and vitreous status critical for decision-making

2. All procedures possible: filter, NPDS, tube shunt, cyclophotocoagulation, others

3. Results of filters – pseudophakic eye (Shingleton, Alfano 2004)
   a. 52 eyes – minimum 1 year f/u, mean 3 years
   b. Stable vision
   c. IOP mean pre-op 25 mmHg, mean post-op 13 mm Hg
   d. Meds mean pre-op 3.3, mean post-op 1.0

4. Virgin conjunctiva results not different from previously manipulated conjunctiva, if conjunctiva reasonably mobile

5. Overall success slightly greater in phakic versus pseudophakic eyes (superior incision): Takihara et al; equal results: Supawavej et al

H. **YAG LASER CAPSULOTOMY IN PATIENTS WITH GLAUCOMA**

1. 1/5 patients have IOP ↑ > 5 mmHg; 3% > 10 mmHg (Barnes et al)

2. IOP ↑ develops within first hour

IV. **Post-operative care for cataract/filter combined procedure**

A. Early compression at edge of flap (Traverso maneuver)

B. Laser suture lysis (LSL) - increase flow through tight scleral flap
   1. Early LSL (day 3 - 10) if no mitomycin used
   2. Delay LSL after 2 weeks, if possible, when mitomycin used. Minimize hypotony. Beneficial effect of LSL in mitomycin eyes up to months after surgery
   3. Argon or Krypton laser: 50 microns, 250 - 1000 mw, 0.1 seconds
   4. Hoskins or Zeiss 4-mirror lens - compress conjunctiva and blanch vessels
   5. Longer sutures easier to cut than shorter sutures
   6. Immediate compression at edge of scleral flap at completion of procedure

C. Releasable sutures - timing same as LSL

D. Consider large diameter (14-24 mm) contact lens tamponade if bleb leak develops - more common with fornix-based conjunctival flaps than limbal-based flaps. Bleb leak may seriously compromise bleb development and must be treated
   1. Kontur - Richmond, CA
   2. Westcon - Grand Junction, CO
   3. Opticken Polymers (McAllister) - Englewood, CO

E. Consider supplemental 5-FU if signs of bleb failure: bleb injection, hemorrhages, vascularization, thickening or localization
   1. 5-FU inhibits fibroblast proliferation
   2. 50 mg/ml concentration 1.0 ml injected subconjunctivally 180° away from bleb – move toward bleb with time. Can also needle flap directly to separate adhesions
   3. Topical proparacaine; 30 gauge needle; 1 cc syringe
   4. Titrate use to clinical response
   5. Hold for conjunctival wound leaks or large corneal epithelial defects; SPK common and not a contraindication to use
6. Use with intensive steroids and digital pressure

7. Keep vial of 5-FU away from light - preserve potency

8. Couple with direct needling of scarred bleb with episcleral cap (Lederer/Mardelli technique) – with or without 5-FU or mitomycin

9. Surgical revision – internal, external or refilter new site

F. If Tenon's cyst (encapsulated bleb) develops

1. Critical time for diagnosis: 1 - 4 weeks post-op

2. Critical time for treatment: first 16 weeks post-op
   a. Digital compression
   b. Medical therapy
      (1.) Glaucoma medications
      (2.) Topical steroids
      (3.) 5-FU
   c. Needling
      (1.) Outpatient, at slit lamp, topical anesthesia
      (2.) Couple with 5-FU or mitomycin
      (3.) Repeat weekly prn
      (4.) Very effective
   d. Surgical revision

G. Hypotony

1. Associated with mitomycin, avascular blebs and may lead to CME, disc edema. Occurs less in combined procedures than primary filters

2. Treatment
   a. Close bleb leak if present
   b. Autologous blood injection, subconjunctival
   c. Laser
   d. Cryo
   e. Surgery – multiple options: suture flap, compression stitch, patch graft, excise devitalized bleb, conjunctival flap, posterior segment surgery

H. Bleb development with combined procedures often less than that seen with primary filters alone

V. History → New Frontiers

A. Modern Era

1. 1970's: ICCE/filter or cyclodialysis; preferably filter first

2. 1980's: ECCE/trabeculectomy
   a. Viscoelastic development
   b. IOL advancements
   c. LSL/releasable sutures

3. 1990's: Phaco/trabeculectomy
   a. Small incision
   b. Foldable IOL's
   c. Antimetabolites

4. 2000: Greater appreciation of potential for separation of procedures: simultaneous or delayed – phaco effect on IOP, non-penetrating deep sclerectomy procedures; "bleb-less"

5. 2010: New ab interno and ab externo approaches – MIGS procedures utilizing TM/SC and uveoscleral outflow pathways

B. New Frontiers

1. IOL's through smaller incisions
2. Field enhancing IOL
3. Medicated implants (neuro-protective, neuro-regenerative, IOP lowering)
4. Continuous intracameral measurement of IOP via IOL
5. Improved antimetabolites
6. Photodynamic therapy of conjunctiva to modulate fibroblast proliferation
7. Development of non-filter based surgical procedures to reduce bleb-associated problems
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