Ultrasound Guided Prostate Implants
Task Group - 64
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TG-64 Report

- History
- Procedure
  - Volume Study
  - Treatment Planning
  - Seed Preparation
  - Implant
  - Final Dosimetry and Implant Evaluation
- Medical Physics Insights regarding USGPI's

History of Prostate Implants

- Pasteau and Degrais - 1913 Radium Intra-urethral
- Radium tubes inserted through the perineum or bladder
- Flocks - 1952 Injection of Colloidal Gold-198
- Gold-198 seed implantation
- Brachytherapy treatment of the prostate died out in the 1960's due to technical difficulties and complications as well as EBRT's advance
- I-125
  - Hilaris and Whitmore MSKCC - 1972
  - Retropubic approach - open procedure with direct visualization of the prostate
  - 5 yr survival - 79% 606 patients
    - 96% survival T1
    - 76% survival T2
    - 69% survival T3
    - 13% survival T4
- Comparison with EBRT
  - Morton and Peschel - Yale University 1988
    - Retropubic Implant vs EBRT - 9 year disease free survival
      - 88% vs 74% for stage A2
      - 62% vs 63% for stage B
      - 30% vs 37% for stage C
  - Schellhammer et. al.
    - Retropubic Implant - 5 year disease free survival
      - 95%, 65% and 34% for well, moderate and poorly differentiated lesions

Complications of retropubic prostate implants

- Fowler et.al.
  - Intraoperative
    - nerve injury 4%
    - excessive bleeding 2%
  - Postoperative - 23%
    - lymphoceles, hematomas, abscesses, celluitis and wound complications
    - pulmonary embolism, - 7%
    - obstruction

- Late complications - 28%
  - lymphedema, voiding symptoms, rectal symptoms, impotence, wound healing, hematuria

- Retropubic approach
  - Poor seed and dose distribution
  - Significant complications
  - Poor long term clinical control
  - Walsh nerve sparing prostatectomy
  - High energy EBRT
- Nag 1985 - TRUS and Fluoroscopy guided implants
- Blasko, Grimm and Ragde
  - Seattle technique
  - Popularized prostate implantation

Advantages of the Transperineal Approach

- Avoids the morbidity of laparotomy
- Outpatient procedure
- Early recovery and return to normal patient lifestyle
- Minimal bleeding
- Low long term morbidity
- One time procedure
- Well tolerated
- Maintenance of sexual function

Procedure for Implantation

- Volume study
- Planning
- Seed preparation
- Procedure
- Final Dosimetry and Evaluation

Volume Study

- Stepwise ultrasound scans through the prostate
- Patient in same position as during implant procedure
- 1/2 cm steps
- Virtual grid on US scan
- Displacement of Prostate by US probe
- Volume determined by CT, MR and US
  - Not in agreement
  - Plexus - Neuro-vascular
- US - Gold standard for Volume determination in Urology
  - Deformation of Prostate by probe
  - Prolate elipsoid
    - 4/3 Π a b c
    - 4.19 a b c
    - 0.52 A B C

US vs CT vs MRI Prostate

- CT - largest volume
  - 15-30% larger than US
- MRI
  - Variable, but slightly larger than US
- US
  - Used for planning
  - Margin may be used

RTOG Study Margin

- Expand US volume 2-3 mm in the anterior dimension
- Expand US volume 2-3 mm in the lateral dimensions
- Maintain posterior border
- Expand US volume 5 mm cephalad and caudad

RTOG Study

- CTV - Clinical Target Volume
  - Pre-implant TRUS prostate
- PTV - Planning Target Volume
  - Expanded CTV
- ETV - Evaluation Target Volume
  - Post implant CT definition of the prostate

Planning

- Transfer US images to TPC
  - Digitize images
    - Prostate
    - Urethra
    - Other structures
  - Capture video image in computer
    - Contour prostate and urethra on screen
  - Add appropriate margins
  - Overlay implant template
- Determine prescribed dose
  - 144 Gy I-125 Implant alone
  - 120 Gy I-125 XRT + Implant
  - 115 Gy Pd-103 Implant alone
  - 90 Gy Pd-103 XRT + Implant
- Distribute seeds in prostate using TPC tools
  - Follow one of several philosophies
- Guess initial activity and adjust seeds and activity as needed

Prostate Margins

- Margins constitute dose escalation
- Increase in seed number and seed strength
- Seeds in dissolvable suture
- Seed placement error
- Neuro-vascular bundle
- Seed migration to lung

Seed Placement Philosophies

- Uniform Loading
  - 1 cm grid
- Modified Uniform Loading
  - Eliminate seeds around the Urethra
- Non-Uniform Loading
  - Uniform loading with several central needles removed
- Peripheral Loading
  - Either high activity or 2X the number of seeds on the periphery

Implant Philosophies

- Seed activity
- Urethral dose
- Rectal dose
- Seed placement error
- Seed migration
- Prostate size
- Seed Number

Implant Philosophies

- All approaches can meet goals
  - Coverage
  - Urethral and rectal sparing
- DVH analysis of preplan
  - Compare different implant philosophies
  - Adjust seed Air Kerma Strength to optimal
- Automated methods of preplanning
  - Yu et. al.

Rational for Modified Uniform and Peripheral Loading

- Disease is in periphery of the prostate gland
- Location where seed location is most critical is the periphery
- Lower Urethral dose
- Dosimetry
- Patterson Parker

Source Activity

- SmPD - Total source strength required to achieve 1 Gy in the mPD
- Source strength calculated from nomograph or formula
  - Lowell Anderson
    - I-125 $S = 0.014\ d^{2.05}$ U/Gy-mPD
    - Pd-103 $S = 0.056\ d^{2.22}$ U/Gy-mPD
  - Source stength per Gy of MPD
    - I-125 $S = 0.011\ d^{2.2}$ U/Gy-MPD
    - Pd-103 $S = 0.036\ d^{2.56}$ U/Gy-MPD

Plan Evaluation

- Root mean square deviation of the peripheral dose
- PUN - Peripheral Uniformity Number
  - 0.67
  - Ratio of mPD and mean peripheral dose
- CN - Conformation Number
  - Ratio of volume of the PTV to the volume enclosed by the mPD isodose surface
  - 0.72

Plan Evaluation

- CI - Coverage Index
  - Percentage of the target covered by the isodose level
  - 100% in plan
  - 90% in post implant dosimetry
- Three D tools
  - Visualize dose cloud and prostate
  - Adjust for minimum activity to cover
    - Margin

Prostate Volume

- Average volume implanted at UIHC - 36.5 cc
- Measured by US slice area integration
- 3 Axis estimate of volume vs integrated volume
  - Average difference 6.3%
  - Maximum difference 19%
- Maximum size for implant 50-60 cc
- Larger prostates have been implanted with difficulty

Average Activity Implanted

- 100 mCi of Palladium
- 1.3 - 1.4 mCi per seed
- Range of seed activity 1.10 to 1.46 mCi
- 91 Seeds on average
- Range of seed number 33-127

Number of Needles

- 20 Needles average
- Range 14 to 26
- Needles on 1 cm Grid for accessibility

Isotopes

- I-125 seeds
  - 60 day half life
  - 27-35 keV x-rays and 35.5 keV gamma ray
  - 144 Gy typically prescribed (formerly 160 Gy)
- Pd-103
  - 17 day half life
  - 20-23 keV x-rays
  - 115 Gy typically prescribed

Seed Preparation

- Leak testing of seeds
  - Usually done by manufacturer
  - Check containers for residual radioactivity
- Calibration of seeds
  - 10% of seeds individually
  - 10% of seeds 5 at a time
  - Batch assay
  - Cartridge assay
  - Autoradiograph

Seed Assay

- Measure 10% of seeds individually
- Measure seeds in bulk
- Measure seeds in cartridge
- Measure several seeds and perform autoradiograph
  - qa of loading
  - seed uniformity

Seed Sterilization

- Must be done in cooperation with Nursing or ID
- Container must allow steam to reach the seeds
- Seeds are NOT self sterilized due to radiation
- Seeds may be loaded under sterile conditions
- MP should become familiar with sterile technique
- Sterilization is time limited

Seed Sterilization

- Steam sterilization
- Flash sterilization
  - 270 deg F (132 deg C)
  - 27 psi
  - 4-5 min
  - 20 min drying time
- Do not steam sterilize rapid strand
- Do not steam sterilize loaded needles

Seed Sterilization

- Steam must be able to reach seeds
  - Loosened cap or access holes
  - Cotton plug in vial
  - Care taken to prevent seeds from being evacuated from containment
- Container may be double wrapped in towels
  - Allows handling and storage

Seed Loading

- Load seeds into needles as per plan
  - Plug end of needle with bone wax or rectal suppository
  - Seeds and spacers loaded as per the plan
  - Loaded needles placed in needle box which corresponds to the plan and template
  - Loading done under sterile conditions after the seeds have been sterilized

Mick Applicator

- Seeds loaded into cartridges
- Seeds delivered loaded into cartridges
  - Reusable cartridges
  - Disposable cartridges
- Seeds calibrated in cartridges
- Seeds loaded into lunch boxes and sent for sterilization

Insertion of Seeds

- Preloaded Needles
  - Seeds loaded into needles
  - End of needle plugged with bone wax
  - Spacers (dissolvable suture) placed between seeds
  - Rapid Strand
- Mick Applicator
  - Seeds placed in cartridges
  - Mick Applicator attaches to needles

Image Guidance

- Needles seen on Ultrasound Image
- US machine places a template onto the image
- The US image’s template corresponds to a physical template lying against the peritoneum
- Needles appear as bright “stars” on the US image
- The needle track is aligned at two points
  - Parallel needle tracks are obtained

OR Equipment

- Ultrasound machine
- Ultrasound probe
- Implant software
- Stepper device
- Template
- Stablizer device

- Stirrups

Resultant Dosimetry

- Orthogonal films
  - Accurate Inf/Sup position of seeds
  - Tedious to identify ~100 seeds
  - Three film technique
    - LAO, RAO and AP - 45 degrees apart
    - Automated seed sort routine
  - Not correlated with anatomy
- CT
  - Inf/Sup position dependent on CT slice thickness
  - Difficult to uniquely identify seeds that appear on two adjacent slices
  - Automated seed localization routines
    - Elimination of duplicate seed ID
  - Correlated with anatomy
  - DVH

Dosimetry Evaluation

- D100, D90, D80
  - Dose to 100%, 90% and 80% of the target volume for dosimetric evaluation
- MPD
  - Matched peripheral dose used in conjunction with ellipsoidal approximation for prostate volume
- mPD
  - Minimum peripheral dose - isodose surface that encompasses the planning target volume
- V200, V100, V90, V80
  - Fractional volume of the prostate target that recieves 200%, 100%, 90% and 80% of the prescribed mPD
- Dose volume histograms - Target
- Dose circumference histograms - Rectum & Bladder
- Dose length histograms - Urethra
- V200, V100, V90, V80, D100, D90, D80, DVH, DCH, DLH, MPD and mPD
- Affected by edema (Waterman et.al.)
  - Average swelling 50% post implant
  - Average Half-life for resolution 10 days
- Time of imaging study and seed localization
  - Affects the resultant dosimetry
  - 3 week CT

Evaluation Tools for Prostate Implants

- 3 Axis post plan
- Volume comparison
- Position Histogram
- Dose Volume Histogram
- Correlation to CT
- Correlation to US
- Correlation to MRI

Radiation Safety

- GM and/or Scintillation detector available in OR
- Accounting of all seeds and needles shall be kept
- Scan all personnel and material leaving OR
- Survey each needle after withdrawal from Patient
- Patient exposure rate measured 1 m from abdomen

Patient Release

- NCRP 11 commentary (1995)
- NRC regulations Part 35.75
  - *http://www.nrc.gov/NRC/CFR/index.html*
- State regulations
- Effective dose equivalent to the general public
  - < 5mSv (<500 mrem) to the general public
  - send instructions
- ≤3 mR/hr at 1 m
  - ~0.3-0.4 mR/hr 50 cm
  - NM at 1 m
- Send home with instructions - Requirement
- Not necessary to strain urine and return seeds after release
- Keep appraised of regulatory changes
- Avoid contact with pregnant women for period of time
  - 4 half lives
- Children restricted from lap for period of time
  - 4 half lives
- Sexual intercourse permitted with condom
  - 2 weeks after implant
  - Condom use for 4 half lives
- Any seeds should not be handled directly with hands or fingers.
- Use of a plastic spoon is recommended to handle seeds.
- Any retrieved seed should be stored away from people in a foil wrapped container such as a glass jar.

Equipment

- Involvement in equipment selection
- Imaging shall be verified
  - Grid pattern and template
  - Bucket of water, grid and needles
- Fluro in OR has minimal distortion
- Acceptance test of US uinit
- Applicators, accesssories, stabilizers, etc.

Treatment Planning System

- TG-43
- Check planning system results versus single seed calculation
- Check planning system with dosimetry atlas
- Check planning system with multiple seed calculation

Seed Assay

- Check dosimetry system constancy using long lived isotope
- Chamber calibrated at ADCL
- Survey meter checked before use in OR

Seeds

- National Air Kerma Strength standard
- TG-43 constants
  - Change from 160 to 145 Gy
- Anisotropy
- New seeds
- Changes in seed calibration
  - NIST

Procedure

- Physics staff in OR during procedure
- Accounting of seeds and needles
- Surveys
- Patient release

Post Implant Dosimetry

- Quantitative analysis of implant quality
- DVH's
- DSH
- DLH
- D90
- V200
- D100, D80, V100, V90, V80

Training

- 5 cases under supervision of experienced physicist
- Experienced physicist defined as one who has been involved in 20 or more cases
- Attend training course

Future Directions

- Anisotropy
- Interseed effect
- Tissue heterogeneity
- Biological models
- RBE
- Edema time course
- Differential dose planning and delivery

Future Directions

- Intra-operative seed localization and dosimetry
- Correlation of dosimetry and clinical outcomes
- New seed designs

Discussion

- Seed implants offer an alternative to surgery and external beam radiotherapy
- Advantages
  - Outpatient procedure
  - One day
  - Minimum of side effects
  - Extremely conformal treatment
- Can be used in combination with External Beam radiotherapy as a boost
- Concerns
  - Operator dependent
  - Short history in general practice
  - Cost???
- Physicist plays key role in implant
  - Planning, OR, Safety, Post implant dosimetry, Evaluation of implant, prediction of outcome, feedback to improve technique