High Dose Rate Radiation Therapy

Calibration, Quality Assurance, and Usage

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I have nothing to disclose

Objective

- Understanding of brachytherapy procedure
- Calibration
- Treatment planning system
- Quality assurance protocols
- Radiation safety
**What is brachytherapy?**

- Greek derivation = short range therapy
- First conformal radiation therapy
- Sealed source placed in or in contact with the tumor providing high dose to the tumor with small volumes of normal tissue irradiated
- Prescriptions developed empirically
- More sophisticated with usage of HDR

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- Implant
  - Temporary
  - Permanent
- Dose rate
  - Low dose rate (LDR)
    - 0.4 – 2 Gy per hour
  - Medium dose rate (MDR)
    - 2 – 12 Gy/hr (0.20 Gy/min)
  - High dose rate (HDR)
    - > 12 Gy/hr

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- Source placement
  - Intracavitary
    - Body cavity (uterus, vagina), body lumen (trachea, esophagus)
  - Contact
    - External surface (skin, eye)
  - Interstitial
    - Prostate, breast, skin
Radiobiological considerations became important
- Source position very important
  - High dose gradient
  - Small volumes of normal tissue in high dose area, can be tolerated if 1 - 2 cm³
  - Inside the tumor doses much higher than prescribed

Remote afterloader

Ir-192 source - 10 Ci, one check cable
- 18 channels (new with 30)
- Initially designed for bronchial treatments
- Now: prostate, breast, cervix, head and neck, brain, bladder, esophagus, bronchus, bile duct.
Advantages

- Improves radiation control
  - Less probability of misplacing sources or losing sources
- Disadvantages
  - Expensive
  - Shielding
  - Medical events still occur
    - Incorrect parameters entered
    - Emergencies during treatment

Source description

"Sorry. My new phone looks a lot like my skin gun."
- $^{192}$Ir
  - Electron Capture
  - Gamma source – large spectrum - average energy 0.380 MeV
  - Short half-life 73.84 days
- **Source tests**
  - Review certificate – physical and chemical form
  - Determine air kerma
  - Leak testing
  - Develop a consistent and reproducible method of calibration.

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**Quality assurance program**

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**Source storage and exchange**
- Storage
  - Additional space other than treatment unit
  - Treatment unit secured
  - DOH regulations (agreement state) or NRC
- Retraction in emergency cases
  - Power failure
  - Source stuck in applicator
  - Hand cranks

- Source exchange
  - Every 3 – 4 months, or more frequent
  - Calibration
    - Tools
      - Well chamber 2
        - Measuring volume 245 cc
        - High ionization current
        - At least five measurements at different depths
      - Stationary position
- Chose correct electrometer
- Polarity
- Max/min current
- Test before using
Method

- In air
- Place buildup under chamber
- Calculate Air kerma

\[ S_k = M \cdot N_{sk} \cdot A_{on} \cdot P_{on} \cdot E_{\gamma} \cdot P_{TP} \]

- \( M \) = electrometer reading in nA
- \( N_{sk} \) = calibration factor (Gy h\(^{-1}\) A\(^{-1}\)) from ADCL
- Tolerance 3%
- Time effect (time error)

\[ \dot{M}_f = \frac{M(t_2) - M(t_1)}{t_2 - t_1} \]

- Survey the suite walls
- QA
  - Every source change
  - Every day of treating
  - Monthly
  - Annual
- Policies and procedures
  - Well assigned roles
  - Clear instructions for each team member
  - Follow protocols
  - Physician present at all times

- Day of treatment QA
  - Before treatment delivery
  - Interlocks
  - Check the emergency kit
  - Check radiation detectors, survey meter
  - Source’s first dwell position
    - Films
    - GafChromic
    - Video camera

- Using prostate plastic needle (dist to first dwell position 1240 mm)
  - What do we measure?
  - How accurate are we?
**Is GafChromic better?**

[Image of GafChromic device]

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**What about your own video system?**

[Image of video system in a medical setting]

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[Image of measurement scale]

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Before using verifications
- Outside diameters
- Treating length
- Chose correct size for individual tumor
- Treatment distance from applicator’s surface
- Scan all applicators
- Test for leakage
- Measure output at a calculated point when possible
- **Transfer tubes**
  - Different lengths
  - Visual inspection for mechanical integrity
  - Store to keep integrity
  - Measure length as received
  - Test connection
  - Test transfer of source

- **Clear labeling method**

- **Check transfer tubes using applicators**
  - Keep all dummies in safe containers for integrity
Prostate HDR - applicators
- Needles implanted in gland
- Normal tissue constrains
  - Anterior rectal wall 75%
  - Bladder neck: 80-85%
  - Urethra:
    - 120% HDR + EBRT
    - 105-110% HDR + EBRT (TURP)
    - 110% HDR Monotherapy

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Templates
- Check correct size holes
- Check for locking capabilities
- Prostate needles
  - Metallic
    - Titanium - no artifacts
  - Check first dwell position
  - No markers (dummy)

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Plastic
- Need trocar when inserted
- Scan with markers (dummies)
- Dummy indicates first dwell position
- Must be tested for correctness
- Check coincidence of first dwell position with the dummy
- Check the size
Skin applicators

- Leipzig
  - 3 sizes
  - Tested for first dwell position
  - Test connection
  - Use the plastic cover when treating
  - Correct for scatter when planning

- Valencia
  - No scatter correction needed

Calculations and verifications

- Verify diameter
- Distance of treatment
- The F factor
### Determining the correct position

- Freiburg flap
  - Placement and repeatability
  - Be innovative
  - Scan first day for planning
  - Use tubes that you know the length
  - Check length
  - Scan and test
- Catheter reconstruction

- Contours and plan

**Treatment planning system**

"I love this Executive Assistant software."
- Brachytherapy planning
  - More difficult to implement than external
    - Determine source location
    - High dose gradient
    - QA practices less rigorously defined than external
  - Goal: achieve a dose distribution that will treat the PTV without exceeding normal tissue tolerances
- Parameters obtained
  - Source type, length, number of source positions, spacing, dwell times

- Dose calculation
  - Dose rate:
    \[ D_s(r, \theta) = S_k \cdot \Gamma \cdot G(r, \theta) \cdot g(r) \cdot F(r, \theta) \]
  - Dose at a point:
    \[ D(r, \theta) = D_s(r, \theta) \cdot \frac{T_{1/2}}{0.693} \]

- Commissioning
  - Understand algorithm
    - Using TG-43 dose calculating
    - No heterogeneity corrections
  - Dwell time calculations
    - Requires source strength specifications
  - Convert in dose rate in medium
  - Test cases
  - Test input/output system
  - Verify CT images accuracy
• Plan verification
  • Second hand dwell time and or dose at point calculation
    • RadCalc, Mucheck, others
    • Manual calculation
    • IPSA versus Manual forward planning
  • Constrains
    • Faster
    • Reliability
    • Verify transfers to console
    • Dwell positions
    • Dwell times

• Treatment delivery/set-up verifications
  • Document everything
    • Make the schedule such that plan is dosimetrically checked before treating the patient (film, Mosfet/TLDs)
    • Correct connections: transfer tubes-applicators
    • Correct applicator size
    • Correct insertion/placement
    • Survey patient before and after treatment

Conclusions:
Train and get trained continuously
You are never too cautious
Redundancy is good
Stay informed and up to date

"YOU USED TO BE A LOBSTER? WHAT A CONVERSATION! I USED TO BE A DEMOCRAT!"
### References

1. ICRU 38  
2. TG 40  
3. TG 41  
5. TG 43  
6. TG 59
Design criteria: HDR treatment rooms
- Follow similar guidelines to those of accelerator rooms
- Maze and door must typically be included
- Similar interlocks to those used in accelerator rooms are required

Major Difference:
- All walls are primary barriers
- Why:
  - Source is positioned anywhere
  - Radiation is emitted isotropically and uncollimated from source
  - Work Load specified as air kerma in air per week or year

Determined by
- Max. Source Activity: 370 GBq (10 Ci)
- Max. Pts. Treated per day: 10/day
- Treatment Days: 5/week
- Max. treatment time: 10 min (10 Ci) per patient
- Air kerma rate constant for Ir-192 = 4.1 µGy/m²/cur. h
  = 3.4 X 10⁶ µGy/m²/week
E = (Permissible Limit \times distance^2) / (Work Load \times Occupancy factor)

- B = 2.45 TVLs
- TVL Concrete (Ir-192) = 152 mm
- TVL Concrete (Co-60) = 218 mm

- Brachytherapy Room design features
  - Require radiation monitor at the door
  - Manual afterloading: Warning signs required
  - Remote afterloading: Interlocks at the entrances
- Information required for an authorization to use isotopes for radiation therapy:
  - Description of source/sources used:
    - Isotope
    - Energy
    - Intention of use
    - Type
      - Remote/Remote
      - Manual

- Drawings to scale - including:
  - Direction of north
  - Exact position of the equipment
  - Location of doors and windows
  - Ducts or other penetrations through a wall relevant
  - Identification of rooms (number)
  - Cross sections (above and below?)
  - Exact distances where relevant

- Indications of adjacent areas/buildings
- Any features affecting radiation safety
- Indication of radiation protection measures:
  - Emergency off buttons
  - Monitors
  - Safes for sources
  - Shielding - normal in walls and additional
- Acceptance testing
  - Mechanical and electrical operations of the device and radiation monitors
  - Mechanical and electrical features of the facility
  - Proper operation of the sources
  - Proper operation of the planning system
- Facility testing
  - Door interlock
  - Radiation warning/detectors working
  - Video survey working

- Facility testing
  - CCTV camera function: at console and/or at nurse station
  - Patient intercom
  - Radiation warning lights: inside room, at door entrance, at control console
  - Function of independent audible GMI alarm
  - Door interlock checks
  - Controlled area signs posted and/or illuminated
  - Function of audible time delay interlock

- Machine function
  - Test basic functions by programming and carrying out a simulated treatment
  - Verify that all displays are correct
  - Verify data at console agrees with programmed data
  - Check printout of date, time, source activity, etc.
  - Test backup storage batteries by periodically (once a month) simulating loss of power
  - Test emergency stop
  - Compare machine times with a stopwatch
  - Check source safety lock when fitted.
**Radiation safety**
- Radiation surveys should indicate expected dose levels.
- Personal dosimeters should be used to monitor personal doses especially in situations requiring source transfer from safe to remote unloading machine.
- Simulated emergency procedures should be carried out so that operating staff are well versed in the requisite volume.
- Dose-rate measurements inside the treatment room should be available so that optical path to patient is known before room entry.
- Personal dosimeters available for emergency use.

**Emergency instructions and manuals**
- Operator’s manual
  - Function of the console
  - How to program a treatment
  - Check the time factor
  - Emergencies procedures
- List of authorized users (posted)
- List of names with phone # for emergencies (posted)
- List of error messages

**Physicist manual**
- Radiation survey when receiving new source
- Returning old source procedure
- Source exchange procedure
- Floor plan for room survey
- Check list for QA procedures
- Source calibration procedures

**Nurses manual**
- Physical features of sources
- Functioning of independent radiation monitoring system
**WHY ERRORS?**

- Individual mistakes, lapses in judgment, or device malfunctions
- Transient malfunction of a device (afterloader, applicator, or planning system)
- Failure of a team member to follow established policies
- Making a mistake while following policies
- Relying on policies and procedures which are inadequate

**Failure to follow procedures may be caused by**

- Inadequate training, inadequate supervision, or excessive time pressure.
- Making mistakes while following policies is often a consequence of
  - Inadequate documentation or training
  - Poor intra-team communication

**Poorly designed treatment-planning and remote-afterloader interfaces,**

- An inexperienced or incompetent team member
- Suboptimal working conditions, or
- Excessive time pressure.
Medical events
- Wrong individual
- Wrong radionuclide
- Wrong site
- Dosage differs by more than 20% of Rx if over 3 fractions, and 50% if 3 fractions or less
- Leaking sealed source
- Temporal implants case: if any sources were not removed

What do we do?
- Report immediately to:
  - RSO
  - Oncologist
  - Director
- Report by phone within 24 hrs to DOH
- Written report with plan in 14 days
- Who is informed and by who?

Minor emergencies
- Loose source guide tube connector
- Vault door not properly closed
- Kink in the tube
- Ring not locked, etc.
- Easy recovery actions that allowing treatment to resume
- Major Emergencies
  - Source retraction failure
  - Patient medical emergency
  - Total computer failure, etc.
  - Involve operator, radiation oncologist, the physicist.

- Establish emergency procedures
  - USNRC and TG-59 recommends
  - Users shall learn and periodically retrain to operate the devices and to respond properly to emergencies
  - Written emergency procedures describing actions to be taken, including surgical intervention, should the source not return to the shielded container at the conclusion of treatment
  - Appropriate staff and equipment available in support of these procedures.

- Main Goal of Emergency Procedures
  - Reduce the radiation dose to the patient by retracting the source from the patient as soon as possible
  - Minimize the radiation exposure to personnel performing the source retraction.
Routine emergency equipment

At the console outside the room:
- Sign: "Danger-Open Radiation Source-Keep Out"
- Geiger-Teknix meter – 0.1–100 mR/hr range
- Geiger survey meter – 1–1,000 mR/hr range

Inside the room:
- Emergency Container
- Funnels
- Kelly surgical clamps
- High quality flashlight and fresh spare batteries
- Suture removal kit
- Suture kit

Emergency container

Mobile

Large and deep enough

Radiation survey meters
Hope your HDRs are uneventful
Thank you
??? Questions ???