High Dose Rate Radiation Therapy

Calibration, Quality Assurance, and Usage

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I have nothing to disclose

"We'll pay you in experience, exposure, compliments and gratitude. Just don't ask for monetary compensation."

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

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- 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 cm^3
  - Inside the tumor doses much higher than prescribed

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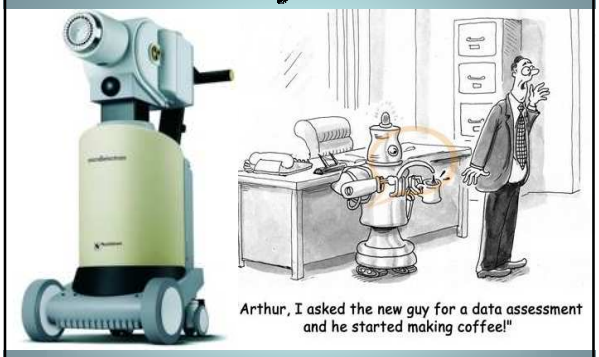
Remote afterloader



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- 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.

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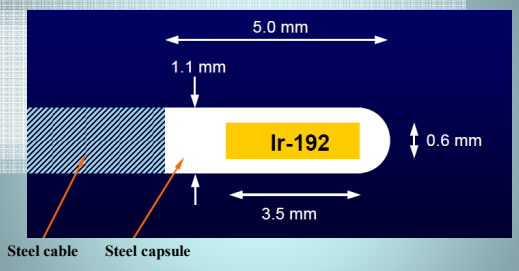
- Advantages
  - Improves radiation control
  - Less probability of misplacing sources or losing sources
- Disadvantages
  - Expensive
  - Shielding
  - Medical events still occur
    - Incorrect parameters entered
    - Emergencies during treatment

Source description



- ^{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

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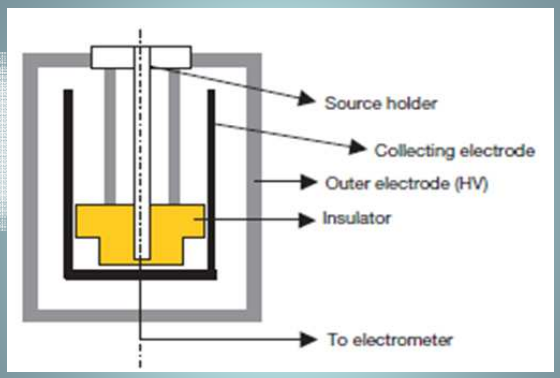
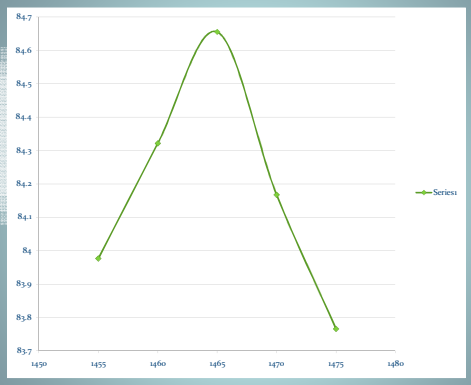
- Storage
  - Additional space other than treatment unit
  - Treatment unit secured
  - DOH regulations (agreement state) or NRC
- Retraction in emergency cases
  - Power failure
  - Source stuck in applicator
  - Hand cranks

- 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





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- Chose correct electrometer
  - Polarity
  - Max/min current
  - Test before using

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"It was always 'Rex, fetch this' and 'Rex, fetch that'. One day I just snapped."

- Method
  - In air
  - Place buildup under chamber
  - Calculate Air kerma$_3$

$$S_k = \dot{M} \cdot N_{s_k} \cdot A_{ion} \cdot P_{ion} \cdot E_C \cdot P_{TP}$$

  - M = electrometer reading in nA
  - N_{Sk} = calibration factor (Gy h^{-1} A^{-1}) from ADCL
  - Tolerance 3%
  - Time effect (time error)$_3$

$$\dot{M}_r = \frac{M(t_2) - M(t_1)}{t_2 - t_1}$$

  - 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

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- 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

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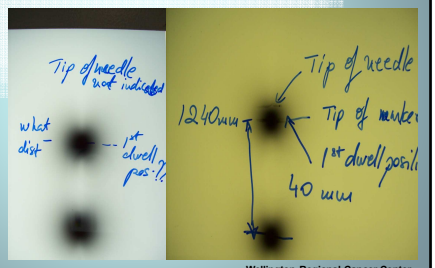
- Using prostate plastic needle (dist to first dwell position 1240 mm)
  - What do we measure?
  - How accurate are we?



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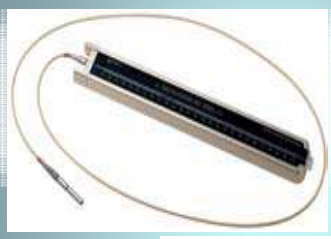
- Is GafChromic better?



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- What about your own video system?

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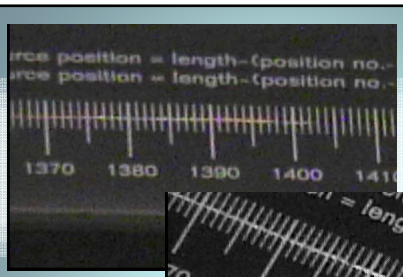

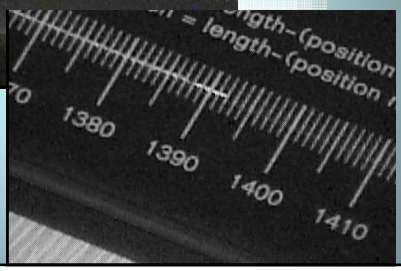

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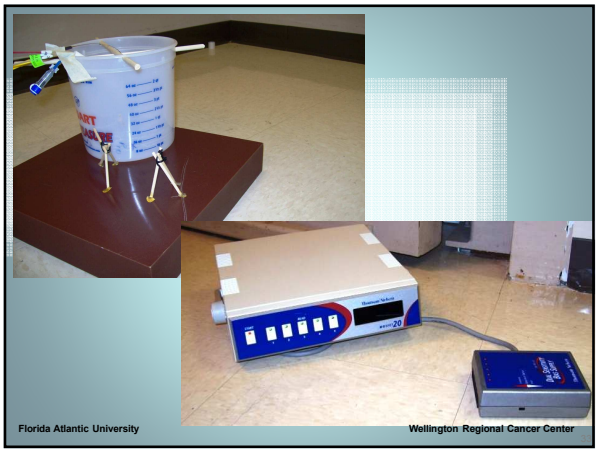
Applicators

- 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

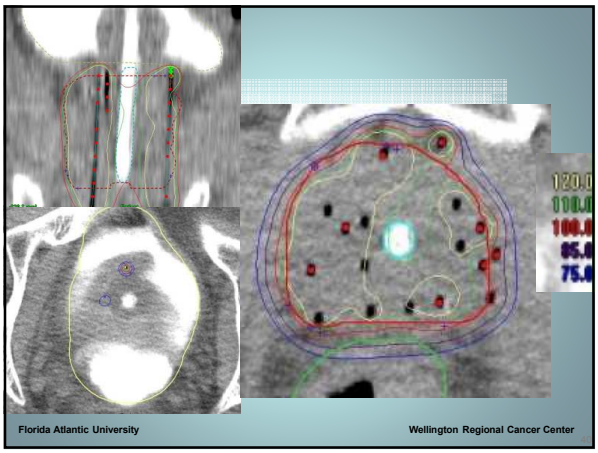
- Check transfer tubes using applicators

- 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

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

- 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

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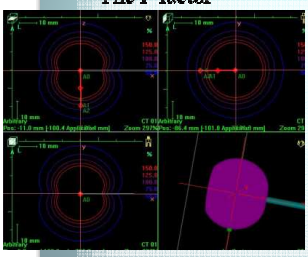
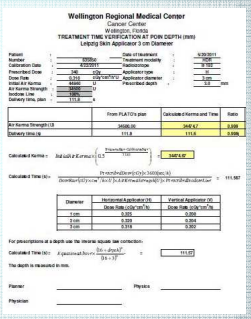
- Calculations and verifications
  - Verify diameter
  - Distance of treatment
  - The F factor





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Cancer Center
Wellington, Florida
TREATMENT TIME VERIFICATION AT PDR DEPTH (mm)
Leipzig Skin Applicator 3 cm Diameter

Patient Number	: 9999xx	Date of treatment	: 6/29/2011
Calibration Date	: 4/20/2011	Treatment modality	: HDR
Prescribed Dose	: 340 cGy	Radioisotope	: Ir 192
Dose Rate	: 0.310 cGy/cm^2/s	Applicator type	: H
Dwell Time Karma	: 1.000	Applicator diameter	: 3 cm
Air Karma Strength	: 34600 U	Prescribed depth	: 5.0 mm
Isodose Line	: 100%		
Delivery time, (sec)	: 111.8 s		

	From PLATO's plan	Calculated Karma and Time	Ratio
Air Karma Strength U3	34600 cc	34612.7	0.999
Delivery time s	111.8	111.8	0.999

Calculated Karma = $3rd\ coll\ K\ Km_{(s)} \left(\frac{Treatment\ Optimal\ Mu}{Mu} \right)$ = 34612.67

Calculated Time (s) = $Treatment\ Dwell\ Time\ (s) \times \left(\frac{Dose\ Rate\ (cGy/cm^2/s)}{Dose\ Rate\ (cGy/cm^2/s)} \right) \times \left(\frac{Treatment\ Dwell\ Karma\ (U)}{Dwell\ Karma\ (U)} \right) \times \left(\frac{Treatment\ Dwell\ Karma\ (U)}{Dwell\ Karma\ (U)} \right) \times (3600\ sec/h)$ = 111.167

Diameter	Horizontal Applicator (H) Dose Rate (cGy/cm^2/s)	Vertical Applicator (V) Dose Rate (cGy/cm^2/s)
1 cm	0.305	0.302
2 cm	0.309	0.304
3 cm	0.310	0.307

For prescriptions at a depth use the inverse square law correction:

Calculated Time (s) = $\frac{Dose\ (cGy)\ \times\ (Depth)^2}{(5 + 3)^2}$ = 111.07

The depth is measured in mm.

Planner _____ Physics _____

Physician _____

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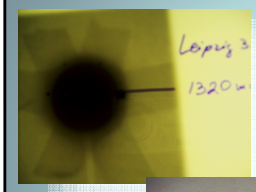
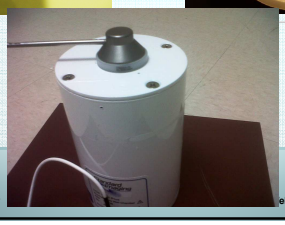
Determining the correct position

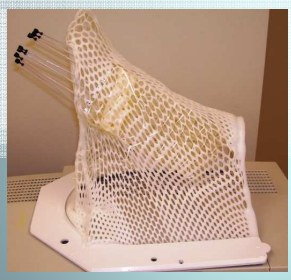


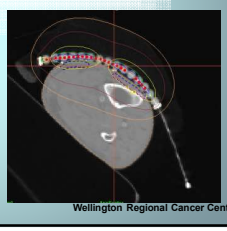


Placement Immobilization

- 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





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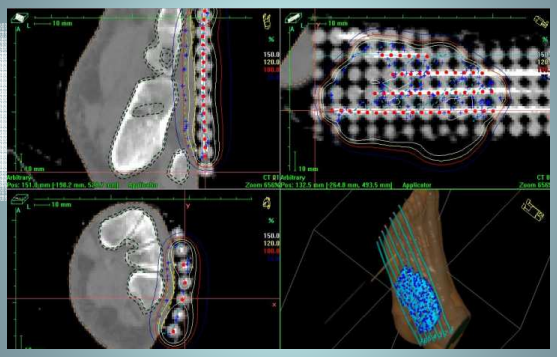
- Contours and plan



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Treatment planning system

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- Brachytherapy planning
  - More difficult to implement than external
    - Determine source location
    - High dose gradient
    - QA practices less rigorously defined then 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

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- Dose calculation
  - Dose rate[5]

$$D_r(r,\theta) = S_k \cdot \Gamma \cdot G(r,\theta) \cdot g(r) \cdot F(r,\theta)$$

  - Dose at a point

$$D(r,\theta) = D_r(r,\theta) \cdot \frac{T_{1/2}}{0.693}$$

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- 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

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- Plan verification[4]
  - 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

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- Treatment delivery/set-up verifications
  - Document everything
  - Make the schedule such that plan is dosimetricaly 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

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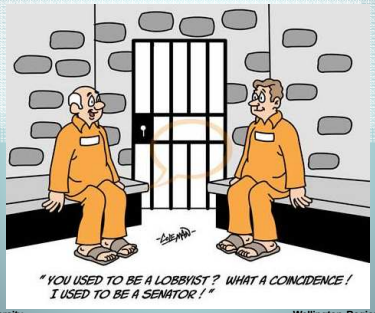
Conclusions:

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



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- References

1. ICRU 38
2. TG 40
3. TG 41
4. "*Dosimetric study of Leipzig applicators*" J. Perez, D. Granero- et all-Int. J Radiation Oncology Biol. Phys, Vol. 62, No. 2, pp 579-584, 2005
5. TG 43
6. TG 59

HDR BRACHYTHERAPY

Radiation Safety and Shielding

Madhu Chilukuri, PhD, DABR

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MITCHELL CANCER INSTITUTE
COMPREHENSIVE ONCOLOGY HEALTHCARE & RESEARCH

- 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

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- 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

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- 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 $\mu Gy.m^2/mCi.h$
  - = 3.4×10^5 $\mu Gy.m^2/week$

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- B = (Permissible Limit x distance^2) / (Work Load x Occupancy factor)
  - B ≈ 2.45 TVLs
  - TVL Concrete (Ir-192) = 152 mm
  - TVL Concrete (Co-60) = 218 mm

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- Brachytherapy Room design features
  - Require radiation monitor at the door
  - Manual afterloading: Warning signs required
  - Remote afterloading: Interlocks at the entrances

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- Information required for an authorization to use isotopes for radiation therapy :
  - Description of source/sources used:
    - Isotope
    - Energy
    - Intention of use
    - Type
      - Remoteafterloader
      - 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

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- Indications of adjacent areas/buildings
- Any features affecting radiation safety
- Indication of radiation protection measures:
- Emergency off buttons
- Monitors
- Safe for sources
- Shielding - normal in walls and additional

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- 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

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- 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 GM alarm
  - Door interlock checks
  - Controlled area signs: posted and/or illuminated
  - Function of audible time delay interlock

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- Machine function
- Test button 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 timers with a stopwatch.
- Check source safety lock when fitted.

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- Radiation safety
  - Radiation surveys should indicate expected dose levels
  - Personnel dosimetry should be used to monitor personnel doses especially in situations requiring source transfer from safe to remote afterloading machine.
  - Simulated emergency procedures should be carried out so that operating staff are well versed in the requisite actions.
  - Dose-rate measurements inside the treatment room should be available so that optimal path to patient is known before room entry.
  - Personnel dosimeter available for emergency use.

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- 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

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- 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

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- 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

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- 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

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- Poorly designed treatment-planning and remote-afterloader interfaces,
- An inexperienced or incompetent team member
- Suboptimal working conditions, or
- Excessive time pressure.

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- Medical events
  - Wrong individual
  - Wrong radioisotope
  - Wrong site
  - Dose 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?

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- 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?

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- 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

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- 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 <u>as soon as possible</u>
  - 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–Muller meter ~0.1–100 mR/h range!
    - Ionization survey meter ~1–1000 mR/h range!
  - Inside the room:
    - Emergency Container
    - Forceps
    - Kelly surgical clamps
    - High quality flashlight and fresh spare batteries
    - Suture removal kit
    - Suture kit

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- Emergency container
  - Mobile
  - Large and deep enough

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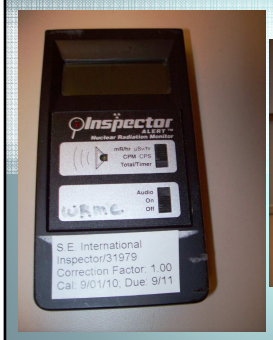
- Radiation survey meters



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Hope your HDRs are uneventful

Thank you

??? Questions ???

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