Comparison of Medical and DOE Health Physics Programs

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Objectives

• To understand basic medical use of radiation producing equipment and radioactive materials.
• To understand operational fundamentals of a Medical Health Physics program as compared to that of a Department of Energy (DOE) Health Physics Program.
• To understand medical personnel and patient radiation safety risks as compared to those risks at a DOE facility.
• To understand medical personnel and patient radiation exposure reduction initiatives.
• To understand the radiation safety differences and similarities from the perspective of being part of both a Medical Health Physics Program and a DOE Health Physics Program.
Palmetto Health

- 8,400 Employees and 1,000 Physicians
- 1,138 Licensed Beds
  - Baptist
  - Richland
  - Children’s Hospital
  - Heart Hospital
- 38 Physician Practices
  - 12 with X-Ray and/or Nuclear Medicine
- 6 Outpatient Imaging Centers
- Opening 5th Hospital in December, 2013.
Palmetto Health Medical Uses of Ionizing Radiation

- Diagnostic Radiology
- CT Scan
- Interventional Radiology
- Nuclear Medicine
- Nuclear Pharmacy
- Cath Lab
- Radiation Oncology
- Blood Irradiation
Diagnostic Radiology

- Diagnostic Radiology is the building block of how radiation is used medically today.
- Consists of basic and complex imaging studies (e.g., lungs, broken bones, Gastrointestinal, etc.).
- Requires a Radiology Technologist to acquire the image and a Radiologist to interpret the image.
X-ray Production

- Electrons accelerated from cathode to a Tungsten Target Anode
- Electrons impede on the target causing the production of X-rays
- Majority of energy departed is heat
Radiographic/Fluoroscopic Unit
Diagnostic Images
CT Scan

- CT scanners are used for complex diagnostic imaging (tumor diagnosis, blood flow, heart studies, etc.)
- First Generation scanners were single slice units with long scan times. Now have multi-slice detectors (up to 320 slices) with extremely short scan times. Typical now is 16 – 64 slice unit.
- Operated by Radiology Technologist with CT Training and images interpreted by radiologists
CT Scan, Continued

- Can identify smaller lesions with CT, which leads to improved treatment outcomes.
- Patient radiation exposure is higher compared to Diagnostic Radiographic studies.
- Chest, Abdomen, Pelvis Study is approximately 2 - 3 Rem
- Initiatives across the Country focusing on patient dose reduction
CT Scan Images
Interventional Radiology

• Uses fluoroscopy (continuous, real time x-ray images) to perform vascular imaging, vascular therapy (stents), ablations, catheter placements, nephrology studies, neuro-interventional, etc.

• Radiologists perform the studies with the assistance of a Radiology Technologist and a Nurse

• Depending on the procedure, patient radiation exposure can be significant

• Neuro-Interventional cases can have skin entrance exposures of 300 – 400 Rad.
Early Fluoroscopy
Interventional Radiology Images
Cath Lab

• Cardiologists use fluoroscopy to diagnose and treat heart failure issues such as artery blockage, atrial fibrillation, etc.
• Similar in scope to Interventional Radiology, but focuses on the heart
Cath Lab Images
Nuclear Medicine

- Uses short-lived radioactive material (Tc-99m, TI-201, I-131, F-18) tagged to a pharmaceutical injected or otherwise ingested by the patient for imaging or therapeutic uses.
- Majority of detectors for imaging are NaI
- Nuclear Medicine is used for a physiological diagnostic study
- Fusion scanners becoming more common
- Nuclear Medicine Technologist inject and image patient. Radiologist/Cardiologist interpret images
Common Medical Radioisotopes

- Technetium-99m: $T_{1/2} = 6.02$ hours
- Iodine – 131: $T_{1/2} = 8$ days
- Thallium – 201: $T_{1/2} = 72$ hours
- Fluorine – 18: $T_{1/2} = 110$ minutes
- Cobalt – 57: $T_{1/2} = 275$ days
- Cobalt – 60: $T_{1/2} = 5$ years
- Cesium – 137: $T_{1/2} = 30.2$ years
- Iridium – 192: $T_{1/2} = 72$ days
- Iodine – 125: $T_{1/2} = 60$ days
Nuclear Pharmacy

• Compounds short lived radioactive material with pharmaceuticals for Nuclear Medicine Imaging
• Potential for elevated staff exposure and requires close monitoring of extremities
• Staff include Nuclear Pharmacists, Nuclear Pharmacy Technicians, Administrative, Drivers
Nuclear Pharmacy Images
Radiation Oncology

- Radiation Oncology uses high levels of radiation for cancer therapy
- Multiple methods are used for treatment:
  - External beam - high energy X-ray
  - Radiostereotactic – external radioactive sources (Gamma Knife)
  - Brachytherapy – internal or radioactive sources (High Dose Rate and Low Dose Rate Therapy)
Radiation Oncology

• There are many different parts to successful radiation oncology:
  – Radiation Oncologist determines treatment
  – Radiation Dosimetrist prepare treatment plan
  – Medical Physicist verifies plans, ensures equipment is within parameters
  – Radiation Therapist sets patient up via simulation and treats patient in accordance with plan.
Radiation Oncology Images
Gamma Knife and Brachytherapy

Gamma Knife

HDR

Prostate Seed LDR
Blood Irradiator

- 5,000 Ci of Cs-137 sealed sources used to irradiate blood
- Prevents certain types of T lymphocytes that can inhibit the immune response
- Annual dose mapping
- Semi-Annual leak tests
Select SRS Facility Operations

- Processing radioactive material for use or stabilization
- Processing high level radioactive waste for stabilization/storage
- Processing weapons grade material to non-weapons grade material for other uses
- Advanced laboratory operations
- Decontamination and Demolition of former reactor, processing and other facilities.
- Transportation and storage of RAM
SRS Facility Radioactive Materials

• SRS facilities have processed multiple materials over the years:
  – Plutonium – 239: $T_{1/2} = 24,360$ years
  – Plutonium – 238: $T_{1/2} = 87.7$ years
  – Neptunium – 237: $T_{1/2} = 2.14$ million years
  – Uranium – 235: $T_{1/2} = 703.8$ million years
  – Tritium: $T_{1/2} = 12.3$ years

• With some of this processing, fission products are produced in the form of waste.
SRS Images
### Medical Radiation Safety Program

#### Staff Safety
- Radiation monitoring
- Appropriate PPE
- Training
- Survey equipment
- Determine/Post Radiation and RAM Areas
- Sealed source Inventory/Leak Test

#### Patient Safety
- Proper protocols
- Determining exposure thresholds
- X-ray equipment quality control
- Education
- Dose Calibrator QC
Medical Radiation Safety Program

- Patient exposure estimates
- Fetal dose estimates
- Proper room/equipment shielding
- RAM Security
- Radiation safety audits
- Radioactive waste management
- Transportation of RAM
- Responsible for ensuring all applicable regulatory requirements are met
- Communicate with regulators
Medical Radiation Safety
Images

Radiation Monitors

Shielding
SRS Radiation Safety Program

- **Staff safety**
  - Planning
  - System characterization
  - Proper PPE
  - Contamination control
  - Radiation and RAM Area posting

- **Ensures radioactive material areas are properly contained**
  - Air flow
  - Surveys
SRS Radiation Safety Program, Continued

- Radiation Monitoring equipment QC
- Monitoring equipment selection
- Ensures overall compliance with DOE requirements
- Ensures effluents are within regulatory requirements
- Environmental protection
- Radiation safety education to staff
Radiation Monitoring

**Medical Program**
- TLD monitors issued to staff, vendors, and physicians
  - Measure whole body, lens of the eye, skin, and extremity
  - Use Effective Dose Equivalent calculation for select personnel
- Air monitoring for I-131
- Thyroid Bioassay

**DOE Program**
- TLD monitors issued to all occupational workers
- Air monitoring
- Environmental monitoring
- Whole Body Counter
- Bioassay via Urinalysis
- Bioassay via fecal analysis
Typical Medical Exposures

- Radiology Technologist
  - Deep Dose: < 500 mrem/year
  - Extremity: <1,000 mrem/year
- Interventional Radiologist/Cardiologist
  - Deep Dose: 3,000 mrem/year
  - EDE: <1,000 mrem/year
  - Lens of Eye: 3,000 mrem/year
  - Extremity: 15,000 mrem/year
- Ancillary Staff (e.g., Surgical Tech, Nurse)
  - Deep Dose: <200 mrem/year
Typical Medical Exposures, Continued

- Orthopedic Surgeon
  - Deep Dose: <500 mrem/year
- Nuclear Medicine Technologist
  - Deep Dose: 500 mrem/year
  - Extremity: 1,500 mrem/year
- Nuclear Pharmacist
  - Deep Dose: 600 mrem/year
  - Extremity: 10,000 - 15,000 mrem/year
Medical Staff Exposure Initiatives

- Multiple overhead shields in Interventional suites
- Portable wall shields for Surgery suites
- Improved pulsed fluoroscopy and specific training on its use for physicians
- Tungsten shields for Nuclear Pharmacy
- 18” long tongs for Nuclear Pharmacy
- Shielded Nuclear Pharmacy hood
- Enhanced glove box for I-131 compounding
Patient Exposure Reduction Initiatives

• CT Protocol Reductions:
  – Estimated patient exposure recorded for every exam.
  – Focusing on X-Ray kVp reduction
  – Use age based protocols
  – Using weight based protocols for chest, abdomen and pelvis CT scans
  – Breast shields for female and pediatric patients
  – Iterative Reconstruction
  – Exposure tracking system to be implemented
CT Breast Shield

- Identified increase in breast cancer risks with radiation exposure in young women.
- Breast Shields can reduce breast exposure by up to 50%.
- Use for every female and pediatric patient.
Patient Exposure Reduction Initiatives, Continued

• Interventional Radiology/Cath Lab
  – Using lower pulse fluoro rates (e.g., 7.5 or 10 pulse per second versus 15 or 30 pulses per second)
  – Exposure (Air Kerma) recorded for every patient
  – Fluoro time thresholds
  – Performing studies to more accurately predict patient exposure to allow exposure thresholds
  – Exposure tracking system to be put in place
Challenging Medical Health Physics Cases

• Nuclear Pharmacist I-131 contamination
  – 300 mCi vial of I-131 spilled in hood
  – Proper PPE not being worn
  – Individual did not report spill
  – Attempted decontamination by their self
  – Contaminated skin when removing gloves
  – Individual did not report skin contamination
  – Went on vacation for 2 weeks
  – Estimated skin exposure of 742 Rad
New Iodine-131 Glove Box Design
Challenging Medical Health Physics Cases, Continued

• Pediatric patient (12 years old) with multiple procedures throughout life.
  – Parents concerned about exposure over life
  – Reconstructed dose

• Multiple Interventional Radiology patients with fluoro times greater than 120 minutes.
  – Maximum is 212 minutes (bi-plane)
  – Some patients followed up with had temporary epilation and erythema identified.
Challenging Medical Health Physics Cases, Continued

• Missing Prostate seed
  – Count in surgery after case
  – Disposition assumed in sanitary sewer

• Annual Limit exceeded for Interventional Radiologist
  – Facility not using Effective Dose Equivalent
  – Left radiation monitor on lead apron
  – Radiation monitor inadvertently exposed to direct fluoroscopy beam.
Cedars-Sinai Medical Center Incident Overview

- Between February 2008 and August 2009, 206 brain perfusion patients received significant overexposures.
- Brain perfusion exposures should be less than 100 Rad.
- Patients received between 300 and 400 Rad.
- Discovered when patients began to complain of patchy hair loss.
Cedars-Sinai Medical Center Incident Overview, Continued

• The master protocol for this study had been changed.
• Due to a misunderstanding about the equipment default settings, the change resulted in excessively high patient doses.
• The change to the master protocol appears to have been intentional, but the result was not.
Mad River Hospital CT Overexposure

- CT Technologist took 151 scans
- Technologist thought unit was not working properly and pushed the button 2 – 3 times
- Patient had hair loss and erythema
Challenging DOE Health Physics Cases

- Plutonium contamination
  - During filter change out
  - Media attention
- “Air Reversal” in rail tunnel air-lock
  - Canyon operations to be shut-down until resolution
  - Actually contaminated waste bags by air monitor
- Working on systems that have been shutdown for extended time periods
Challenging DOE Health Physics Cases, Continued

• Discriminating Radon/"Thoron" in stack emissions.
  – Typical detectors could not discriminate whether elevated levels due to Radon/"Thoron" or Plutonium.
  – Installed system that could, though detectors were sensitive to acidic air.
Medical and DOE Facility Health Physics Summary

Some Key Similarities
- Basic Health Physics fundamentals required
- External radiation monitoring requirements
- Survey equipment
- Training
- Transportation
- Challenging scenarios

Some Key Differences
- RAM half-life and potential hazards
- Radiation produced radiation
- Regulators
- Security
- Potential risk of lost containment and/or exposure
- Staff awareness
- Health Physics Staff size
Contact Information

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