Disaster Preparedness for Health Technology Managers: Issues with Radiation-Emitting Devices and Radioactive Sources

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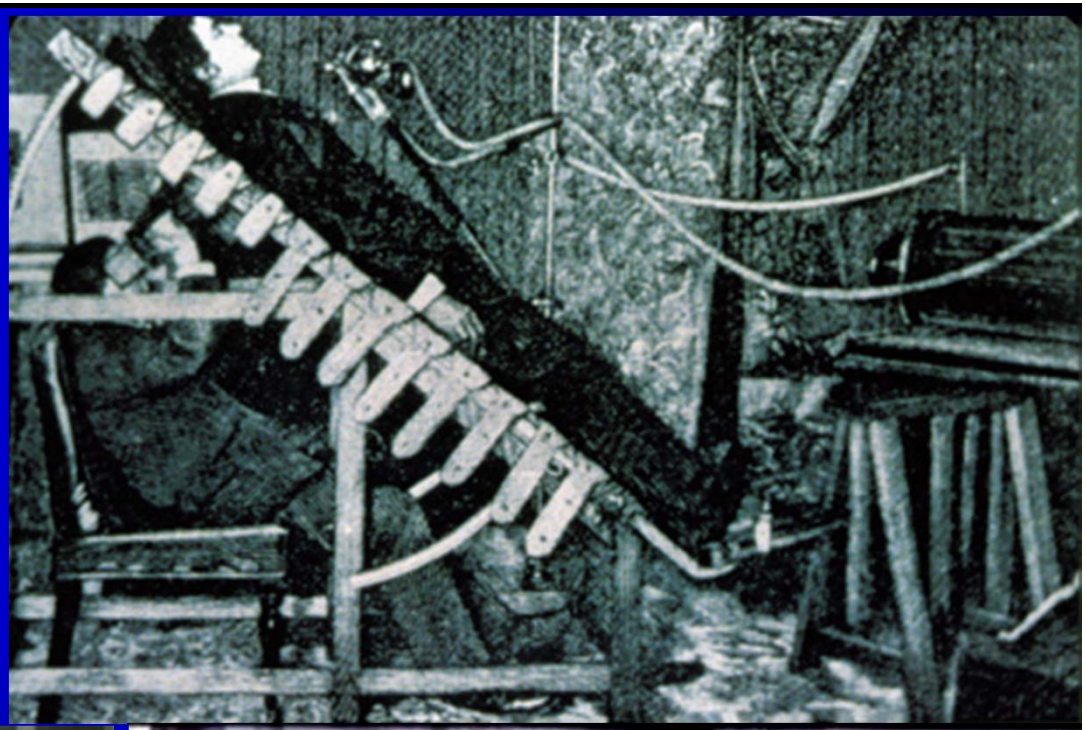
International Union for Physical and Engineering Sciences in Medicine

Radiological equipment has changed a bit since the early days...



Medical Imaging - Today

X Rays

Planar Projection Imaging

- **Radiography**
  (Film or Digital: CR / DR)
  - General
  - Mammography
  - Dental
  - Bone Densitometry
- **Fluoroscopy**
  (Image Intensifier or Flat Panel)
  - Diagnostic
  - Interventional

Volume (3D) Projection Imaging

- Computed Tomography (CT)
- Digital Tomosynthesis

Imaging in Radiotherapy (IGRT)

Non-Ionizing Radiation

- Magnetic Resonance (MR)
  - MRA
  - MRS
  - fMRI
- Ultrasound (US) incl Doppler

Nuclear Medicine

- Gamma Camera
- SPECT
- PET

Hybrid Systems

- SPECT/CT
- PET/CT
- PET/MR
- MR/US
- MR/Optical

RADIATION THERAPY

- External Beam Treatment (Teletherapy)
- Brachytherapy
  - Intracavitary
  - Interstitial
  - Intraluminal
  - Inter / Intraoperative

External Beam Radiotherapy Modalities

- Contact Therapy + < 100 kV X Rays
- Superficial Therapy + 100 to 120 kV X Rays
- Orthovoltage Therapy + 150 to 400 kV X Rays
- "Teletherapy Units" + Cs - 137 and Co – 60
- Megavoltage
  - X Rays
  - Electrons

  + Linear Accelerators
- Heavy Charged Particles + Protons & C, Ar, Ne Ions
- Others + Neutrons, Pions

First Co-60 Unit (1951)

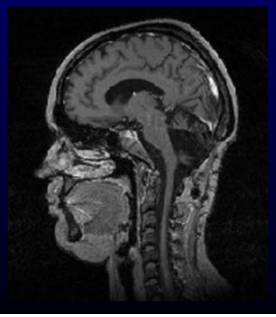
Cs-137 Teletherapy (1960's)

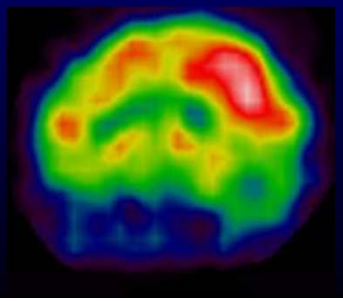
Orthovoltage X-Ray (1990's)

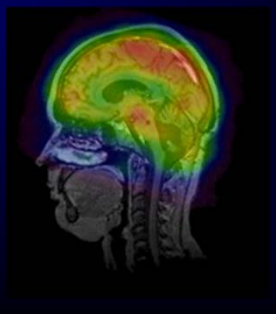
Linac with IGRT (2000s)

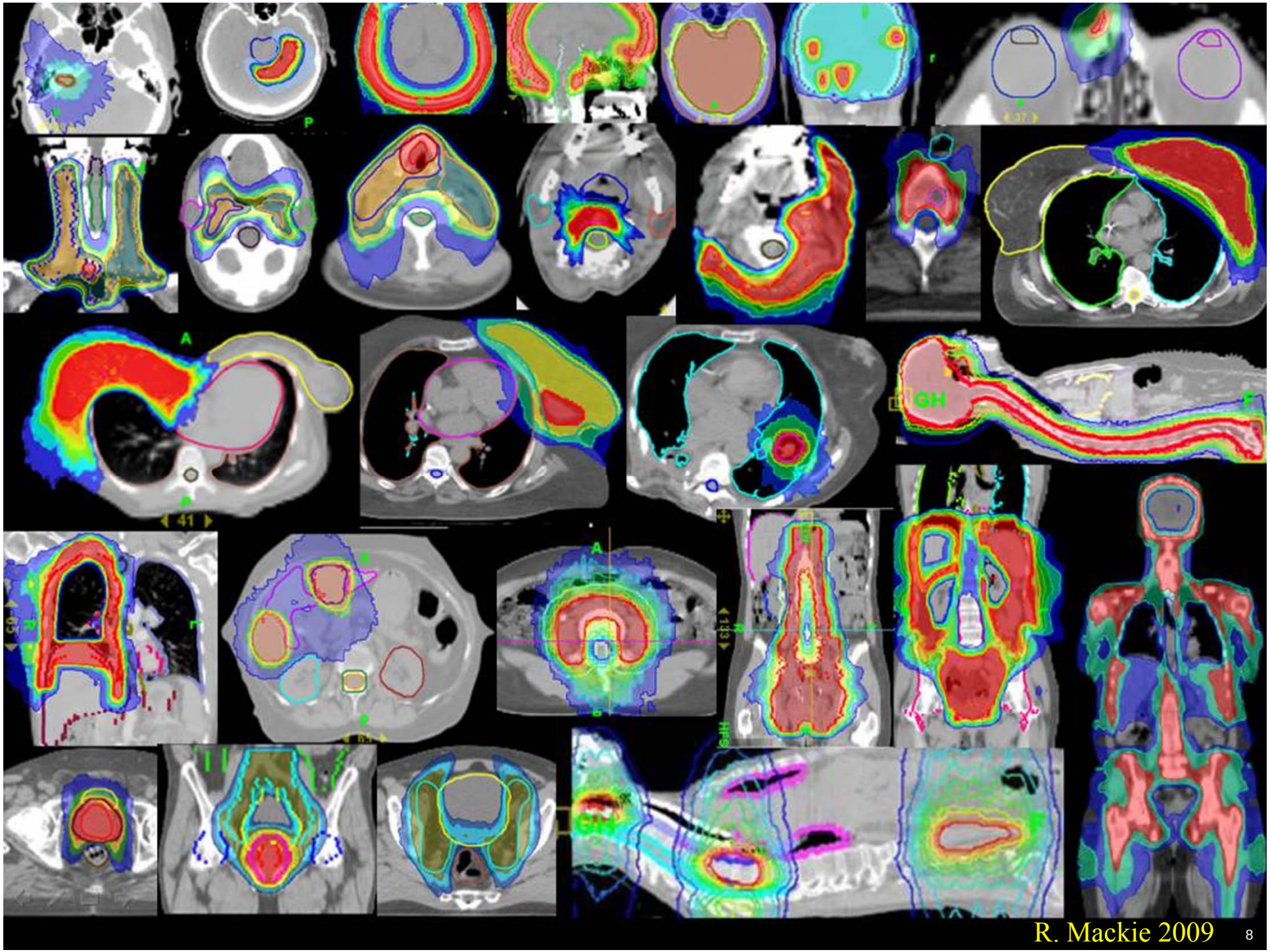
3 - D Treatment Modalities with LINACS

- Conformal Radiotherapy (3DCRT)
- Intensity-Modulated Radiation Therapy (IMRT)
- Intensity-Modulated Arc Therapy (IMAT)
- Volumetric Modulated Arc Therapy (VMAT)
- 4-D Radiation Therapy
- Stereotactic Radiosurgery (SRS)
- Stereotactic Body Radiation Therapy (SBRT)
- Image-Guided Radiation Therapy (IGRT)
- Image Fusion
- Tomotherapy



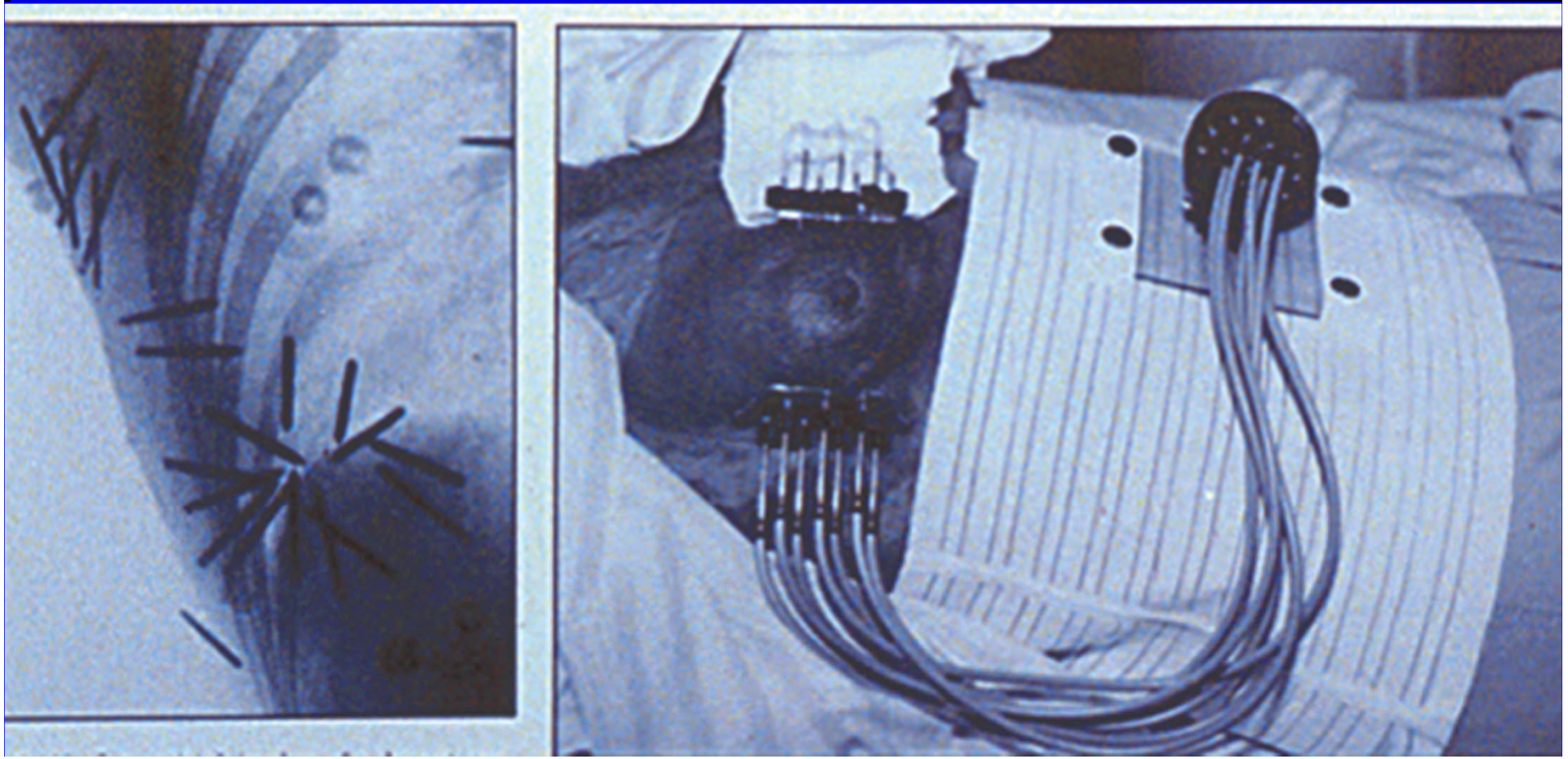


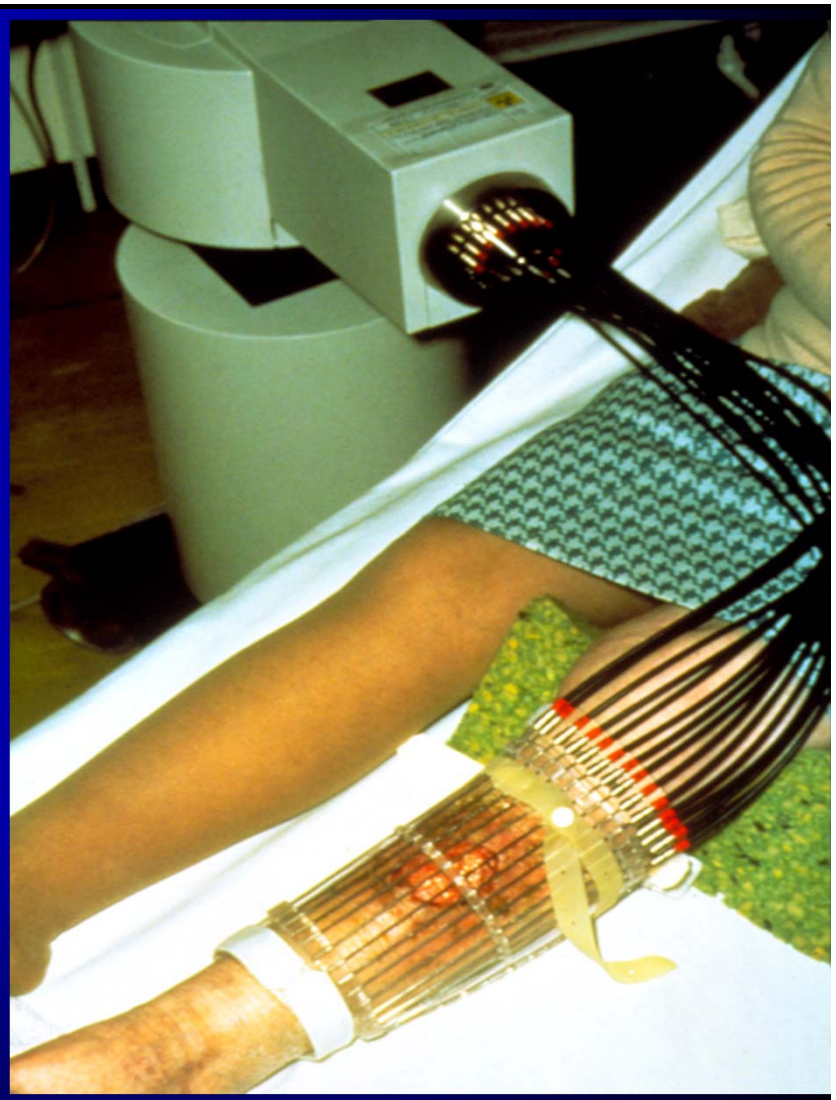



R. Mackie 2009

Changes in Brachytherapy
Breast Cancer Treatment

1929 vs 1990's





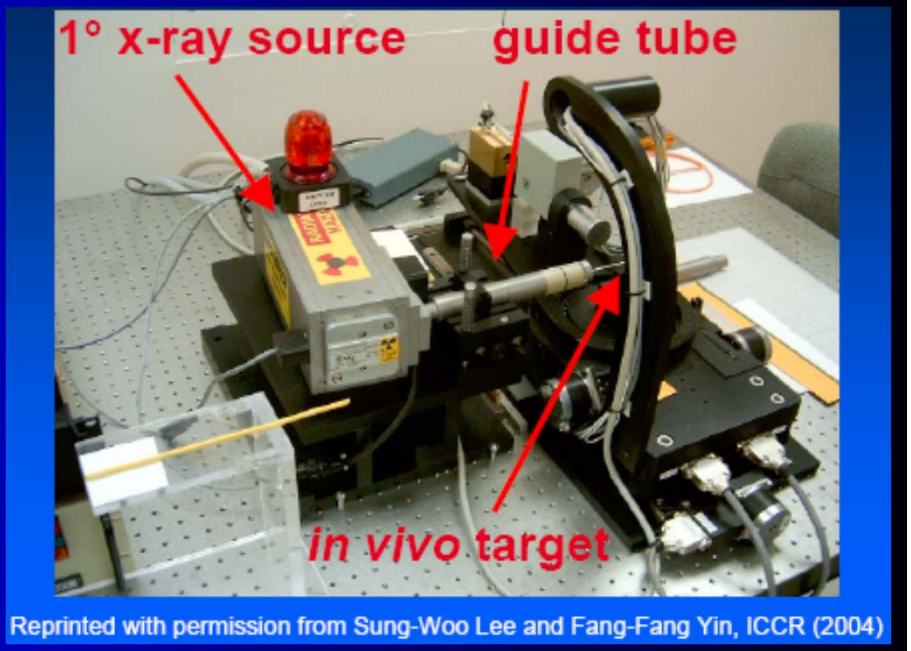
LDR (1970's)

HDR (1990's

Remote Afterloading Brachytherapy Units

Electronic Brachytherapy

Miniature x-ray tubes that can yield similar dose distributions to LDR I-125 and similar dose rates to HDR Ir-192



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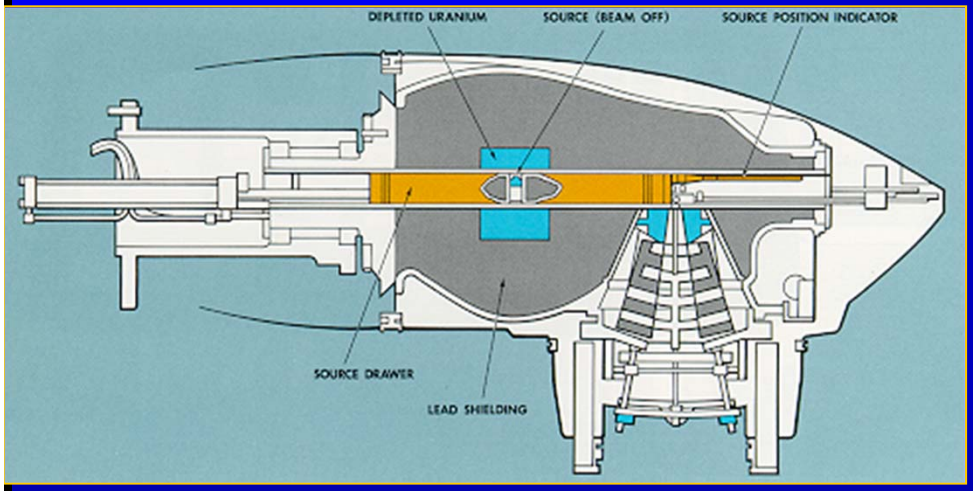
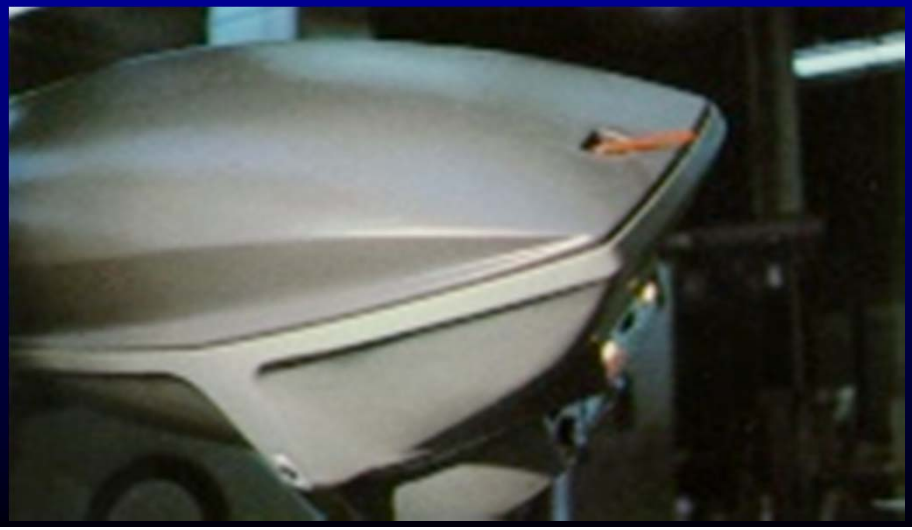
Disaster Types that Affect Hospitals

1. Loss of Radiation Source Control at the Hospital
2. Nuclear / Radiological Event
3. Natural Disasters
   a) Fires (do not have to be “natural”, they could be arson)
   b) Earthquakes
   c) Hurricanes / Typhoons
   d) Floods / Tsunamis

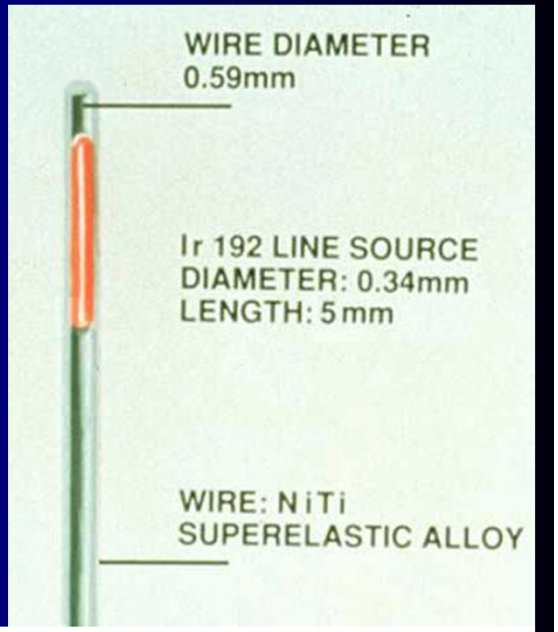
1. Loss of Radiation Source Control at the Hospital: Examples

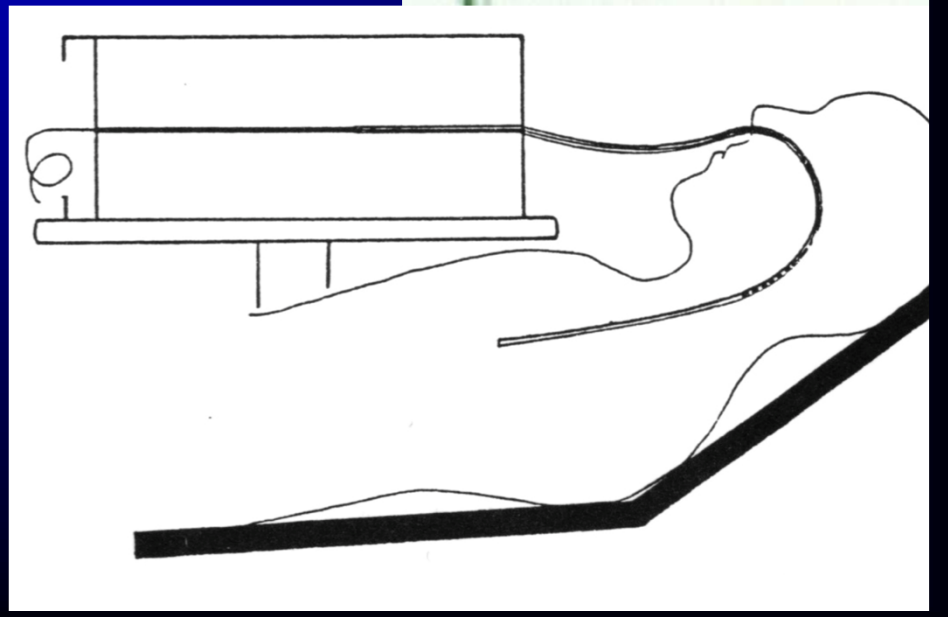


Co-60 Source Stuck

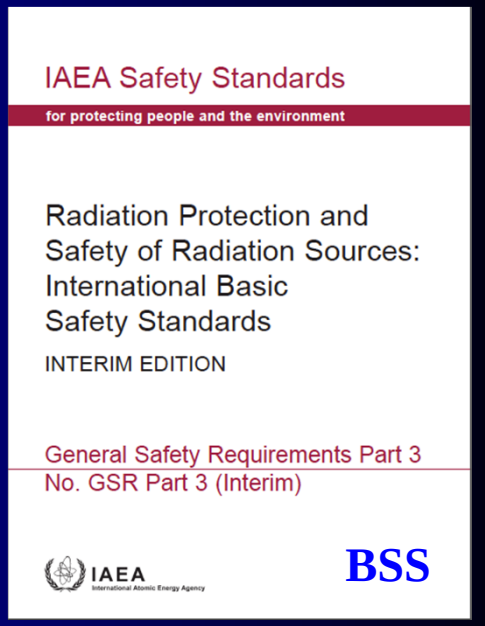


Brachy
Cable
Broken





1. Loss of Radiation Source Control at the Hospital



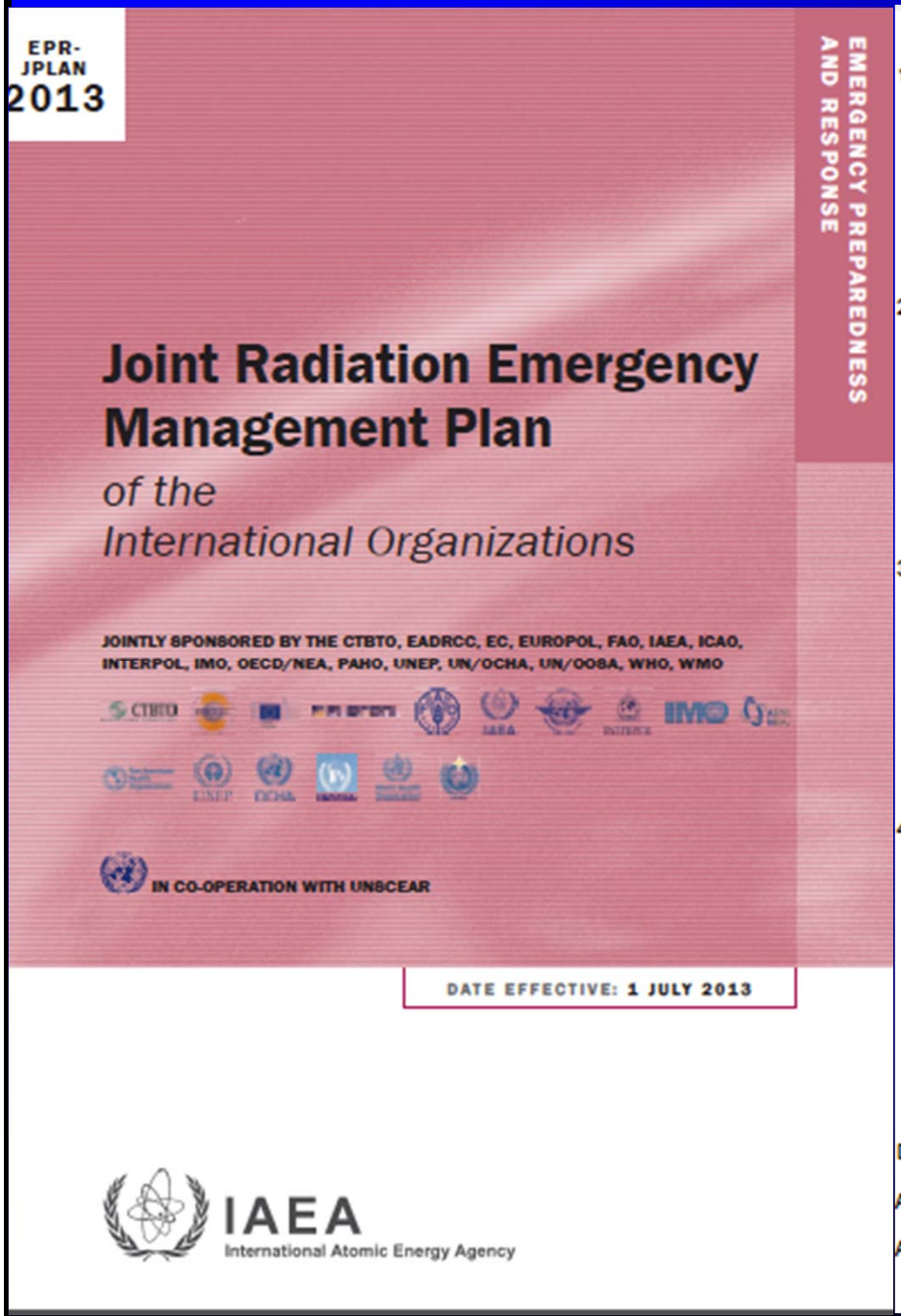
- A BSS-based safety guide for medical applications considers this a contingency not an emergency
- Medical Physicists/Radiation Protection Officers need to have contingency plans and do periodic drills to test the appropriateness of the responses
- Medical devices containing radioactive sources, to prevent patient / staff irradiation in case of a power failure (source would not retract), must have a manual retract assembly and/or a UPS

2. Nuclear / Radiological Event

(Example: Chernobyl radioactive discharges may have affected a hospital in the area)

- **Medical Services may be inoperable if radiation contamination is serious and both patients and staff may have to be relocated**
- **Hospital managers should request help from National Agency in charge of Disaster Response**
- **Country may need international assistance (See *Joint Radiation Emergency Management Plan of the International Organizations EPR-JPLAN (2013)*, published by the IAEA)**

Prypiat Hospital in Ukraine. (Carl Montgomery/flickr)



2. Nuclear / Radiological Event

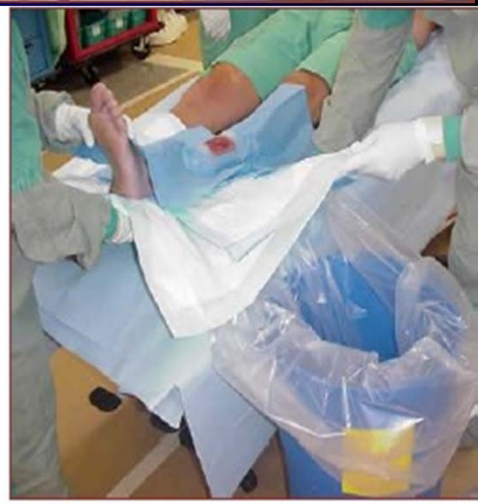
If the hospital be part of the national / regional network of hospitals providing medical care to irradiated or contaminated patients in a nuclear/radiological emergency

- Activate Emergency Plan, that should have been tested in practice drills periodically, and includes coordination with National Disaster Response Agency
- Assemble medical/technical/radiation experts team
- Prepare hospital to provide staff and rooms / areas for:
  - Irradiated patients in need of sterile conditions
  - Radioactivity detection in incoming patients & staff
  - Decontamination

Medical treatment of a contaminated wound (*The medical aspects of radiation incidents*, REAC/TS)







3. Natural Disasters Common Recommendations

Device and building should be built to withstand major potential disasters in the area

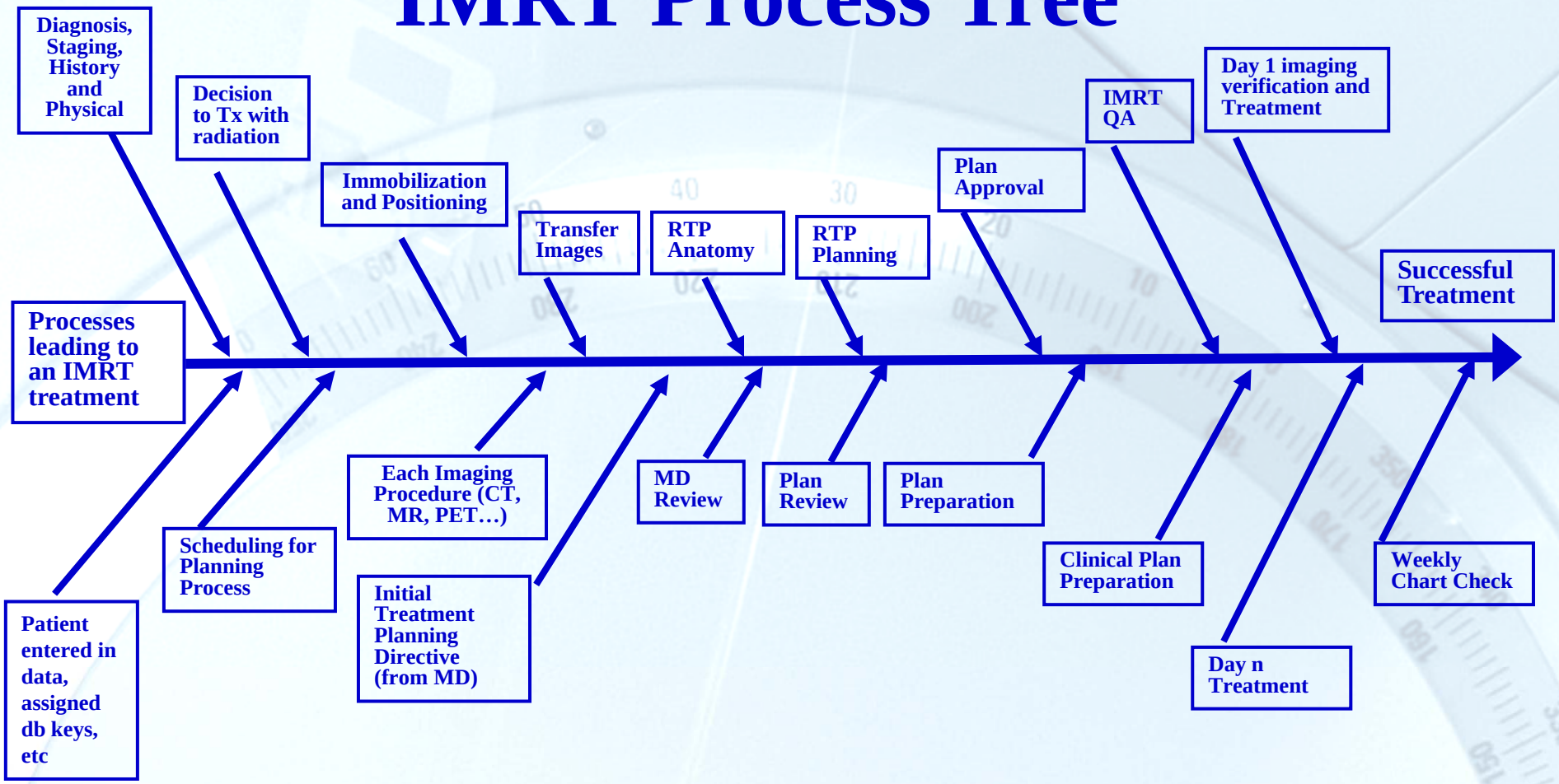
If event occurs when patients are undergoing radiological procedures:

- **Stop exams, interventions or treatments**
- **Move patients to safe location**
- **Record given doses (mu or time) in case of radiotherapy treatments**

3. Natural Disasters
Common Recommendations
After the event

- **Check and correct – if possible – the medical device's mechanical and electrical integrity**
  - Components
  - Accessories, including patients' masks, immobilizers…
  - Dosimetry systems and QA phantoms
- **Assess/repair device's electrical & water supplies**
- **Assess/repair software and network operability**
- **Request medical physicist to perform a complete device evaluation before its return to clinical use**

IMRT Process Tree



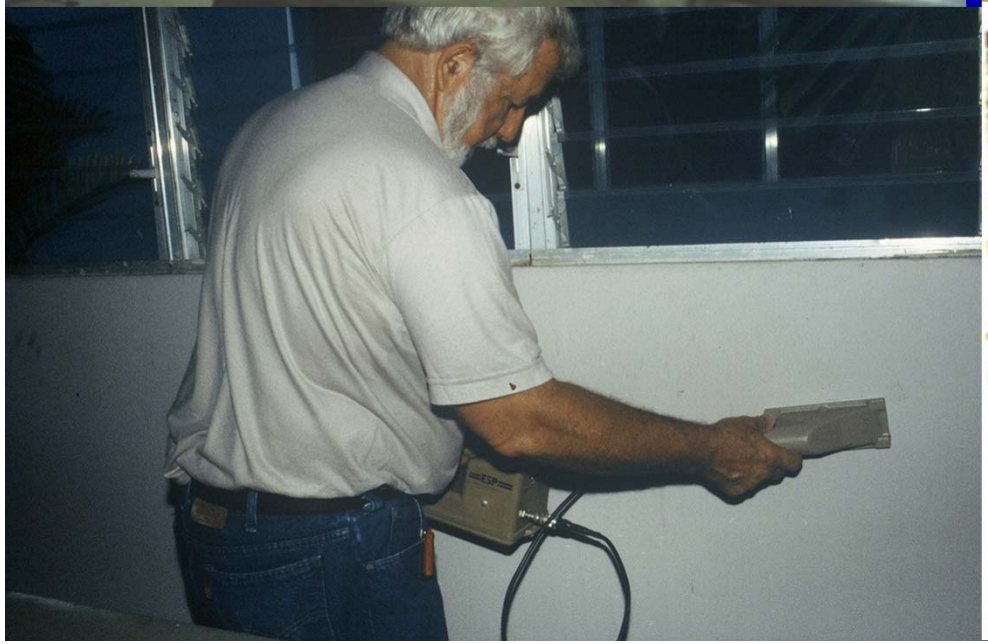
Saiful Huq, chair TG100

3. Natural Disasters Recommendations if Device Contains a Radioactive Source

After the event

- Seal room (prevent access) until radiation protection officer has verified that:
  - Source is still in the device or container
  - Sealed source encapsulation is intact
  - Either no contamination has occurred or
  - Contaminated areas have been decontaminated

Checking for Contamination



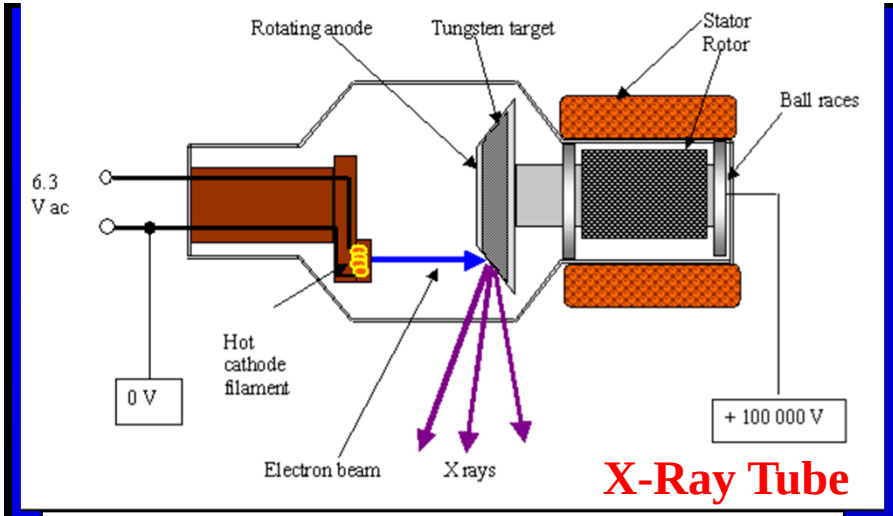
Additional Recommendations for Earthquakes

Depending on the magnitude, earthquakes may affect the alignment of the radiation beam

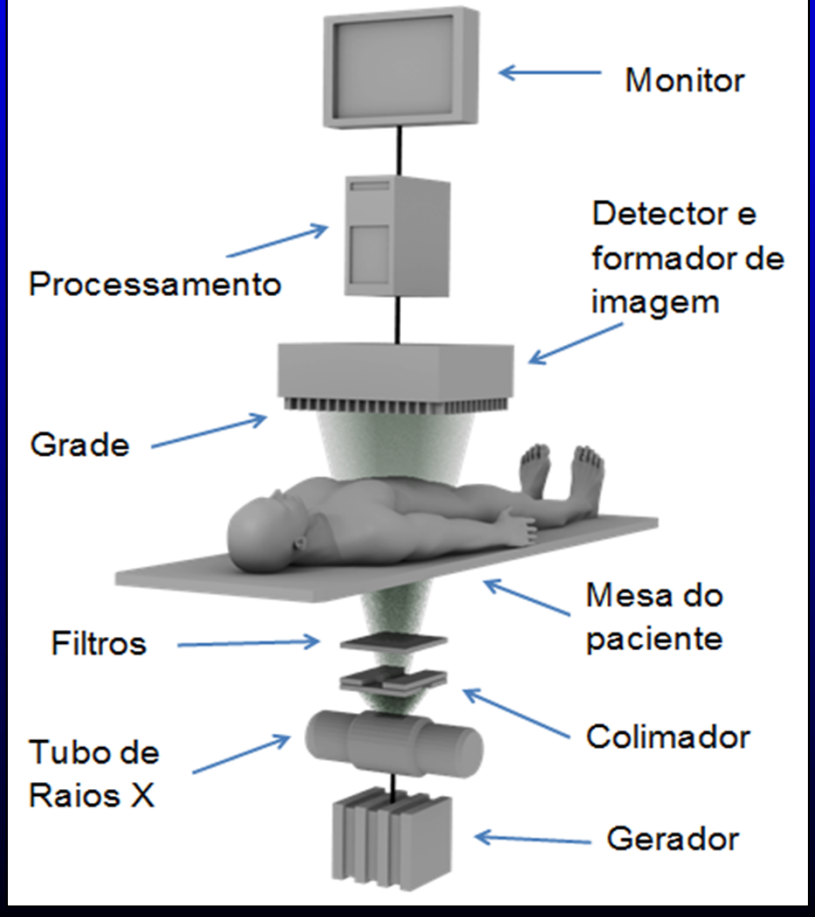
After the event

For medical imaging devices, check:

- **The congruence of the radiation and light fields**
- **The alignment of the whole imaging chain, including displays and networks (RIS, PACS)**



X-Ray Tube



Fluoroscope with Flat Panel Detector

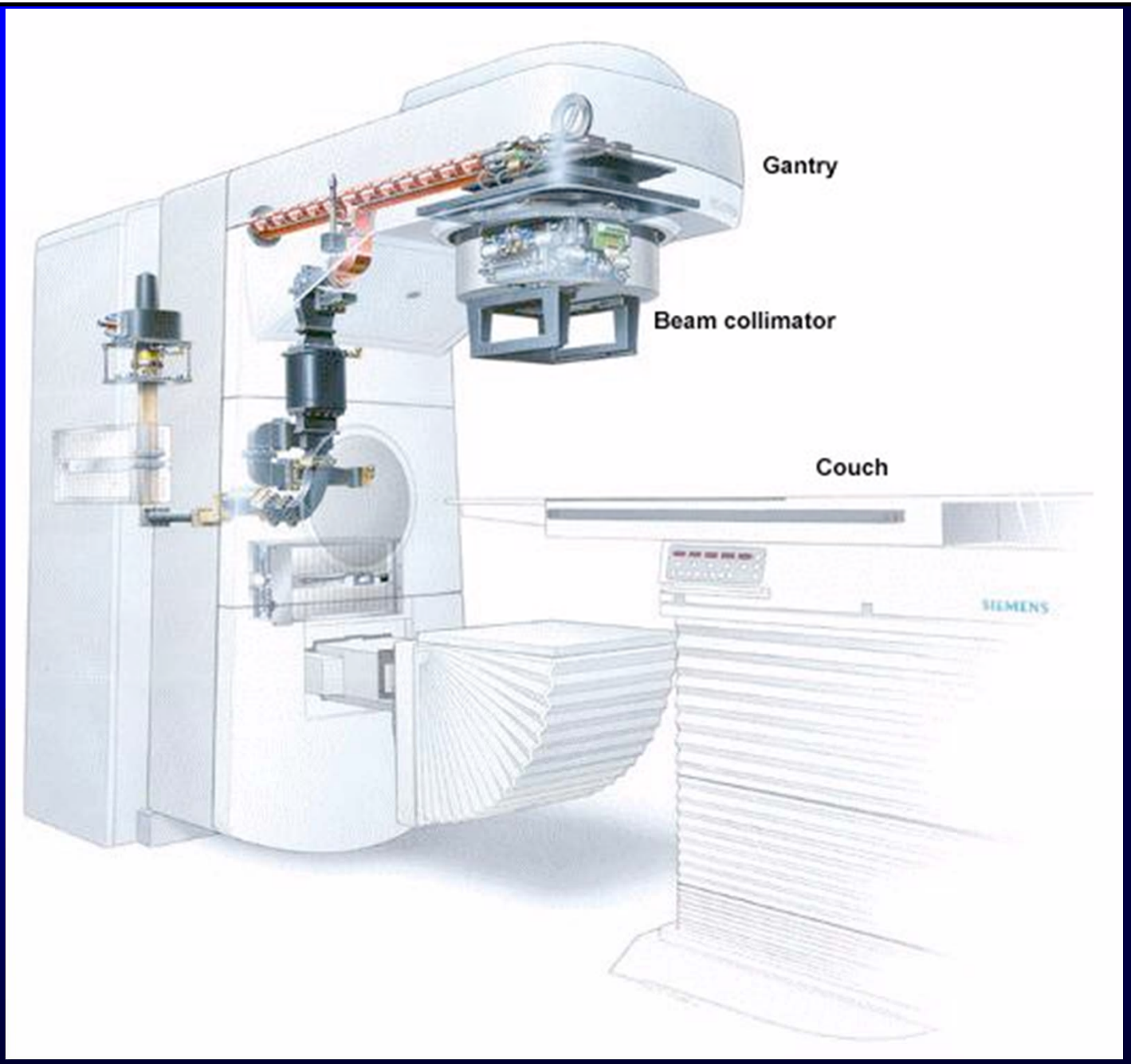
Fluoroscopic Imaging Chain

Additional Recommendations for Earthquakes

After the event

For external beam radiotherapy devices, especially linear accelerators, check:

- Position of collimator, gantry & table isocenters
- Field flatness and symmetry
- All dosimetry and treatment planning systems
- In-room imaging devices (IGRT)
- The record and verify network
- Patient accessories



Schematics of a medical linear accelerator (State University of Campinas, Brazil)

Conclusion

- Medical devices in medical imaging and radiation therapy are very vulnerable to disasters due to their design complexity.
- Prevention and response measures should take into account the medical device itself and its role in the whole radiological process.
- Hospital staff should be prepared to cope with disasters through frequent drills of a well-developed emergency plan which encompasses the phases before, during and after the disaster, and that includes radiation protection considerations.