X-ray imaging dose to therapy patients

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Introduction

• Image-guided radiation therapy (IGRT) significantly improves the accuracy of radiotherapy.
• It plays an essential role in the accurately delivery of highly confirmed dose to target.
• IGRT is the new paradigm in radiotherapy.
• X-ray imaging procedures for patient setup add radiation dose to patients.
• Additional imaging dose may entail risk to patients.

Commonly used x-ray image devices
• MV electronic portal imaging device (EPID)
  o 2D images: portal images
  o 3D images: MV-CBCT
• kV x-ray devices integrated to treatment unit
  o 2D images: digital radiography
  o 3D images: kV-CBCT

Talk Outline

• Compares the amount of radiation exposure to organs resulting from different image guidance procedures
• Presents a perspective view on the imaging dose related to the therapeutic dose
• Suggests techniques to reduce the imaging dose in clinical applications including kV x-ray and MV x-ray imaging
Examples of dose MV setup fields

An Anterior and a Rt lat fields (2 MUs for each setup field)

Fig. 1. The cylindrical ionisation chambers measurement setup. A small volume chamber was placed in the phantom as well as 1 cm below the surface at the 0°, 90°, 180°, and 270° positions.

Dose from MVCT


Fig. 2. Transverse slice of a head protocol patient mixed with (a) 2.5 cGy MV-CT protocol, (b) 5.0 cGy MV-CT protocol. The lower dose is sufficient to show the bone structures on the MV-CT image. Soft tissue boundaries are more visible with the higher dose.

Images of MVCT

Images of MVCT on Tomo unit

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Fig. 3. The helical tomotherapy unit installed at the University of Wisconsin. The left panel is with a cover open. The panel on the right is looking along the CT table into the head gantry.
Dose form MVCT on Tomo unit

Fig. 4. Comparison of MVCT images to KVCT images. Shown are 2 CT slices from a dog with sarcoma of the sinus. (A) Erosion of the bone is shown with the white arrow. (B) The left sinus is filled with tumor. The MVCT image at 2 cGy does not have sufficient contrast for diagnosis but is sufficient for purposes of localization.

kV x-ray devices on treatment unit

2D images: digital radiograph

Dose dependency on depth between kV and MV

Dose dependency on medium for MV beam
Dose dependency on medium for kV beam

Slab of water
20 cm thickness

125 kVp x-rays used for CBCT from a Varian Trilogy

Dose distributions: a single Anterior beam

6 MV beam

110 kVp beam

MV: ~ 1 - 3 cGy
MV: ~ 0.01 cGy

What are the dose profiles along the line AB between MV and kV beams?

Dose distributions: a single Anterior beam

6 MV beam

110 kVp beam

MV: exit dose 40%
kV: exit dose 4%

kV x-ray medium dependency: soft tissues vs. bone


3D images: kV CBCT

200 degree source rotation and the detector is centered
(a) Full fan type scan
360 degree rotation and the detector is shifted to one side
(b) Half fan type scan

Radiation dose dependency on scan techniques: Head

Fig. 4. The CBCT scan does are shown in (a) side view and (b) axial view. Different intensity colors for specific radiation exposure range. The standard head scan does are shown in (c) and (d). The red box shows the loose range of 0 to 2 cGy, whereas the blue box shows the loose range of 0 to 0.01 cGy. The range is less than or equal to 0.5 cGy. The dose is less than or equal to 0.01 cGy. The dose is less than or equal to 0.5 cGy. The dose is less than or equal to 0.01 cGy.
Radiation dose dependency on scanned length: Pelvis

Dose dependency on scan techniques and filters: Pelvis Spot Light

Dose dependency on scan techniques and filters: Pelvis Spot Light

Radiation dose dependency on patient size and scan techniques

Perspective view: EPID (4 cGy) vs. kV-CBCT (~0.3 cGy)

Perspective view: kV CBCT dose continue to decrease
Perspective view: EPID vs. kV-CBCT (Trilogy)

4 cGy x 35 Fractions = 140 cGy
1.5 cGy x 35 Fractions = 52 cGy

Perspective view: EPID vs. kV-CBCT

4 cGy x 35 Fractions = 140 cGy
1.5 cGy x 35 Fractions = 52 cGy

Summary

Doses from image-guided procedures

- MV imaging:
  - MV-EPID: ~4-6 cGy from two orthogonal setup fields
  - Megavoltage cone-beam CT (MV-CBCT)
    - Linac unit: ~1-20 cGy /acquisition
    - Tomotherapy unit: 2-12 cGy

- kV imaging:
  - kV DR: ~0.01 cGy
  - kV-CBCT
    - Soft tissue: 0.1-3 cGy /acquisition
    - Bone: 0.3-6 cGy /acquisition

Summary

- Conventional MV setup fields
  - 4-6 cGy from two orthogonal setup fields
  - For 30 fractions: 100 – 200 cGy additional dose to patient

- kV imaging:
  - Single kV-CBCT
    - 0.1 - 2 cGy (soft tissues), 0.3 - 5 cGy (bone)
  - For 30 fractions: 3 – 60 cGy (soft tissues) and 90 – 150 cGy (bone)
Summary

- **MV imaging:**
  - Dose resulting from MV-CBCT is comparable to that of multiple portal imaging acquisitions
  - Negligible difference between dose to bone and dose to soft tissues

- **kV imaging:**
  - Dose resulting from kV-CBCT is much larger than that of multiple kV DR acquisitions
  - Dose to bone is 2-4 times higher than the dose to soft tissues

Techniques to reduce the imaging dose

- **Improve imaging technology (manufacturers):**
  - The progress is continually being made by manufacturers.

- **Use imaging guidance efficiently:**
  - Choose the procedure and the frequency that is most suitable for the purpose
  - Develop protocols for using image guidance procedures
  - Pay attention to pediatric patients and imaged volume

- **Account imaging dose for radiotherapy patients:**
  - Calculate organ doses resulting from image guided procedures
  - Account them as part of total dose to patients in radiotherapy treatment planning systems
  - AAPM TG-180

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