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.

Introduction

Commonly used x-ray image devices

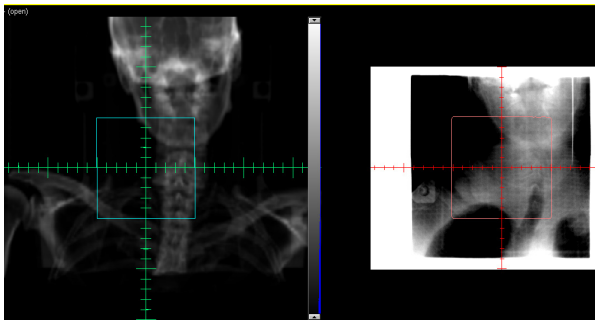
- MV electronic portal imaging device (EPID)
  - 2D images: portal images
  - 3D images: MV-CBCT
- kV x-ray devices integrated to treatment unit
  - 2D images: digital radiography
  - 3D images: kV-CBCT

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

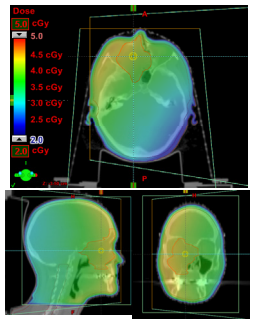
Electronic portal imaging device (EPID)

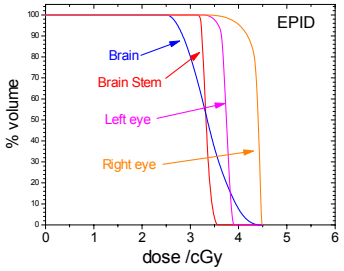
A typical MV setup field



Examples of dose MV setup fields

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





MV CBCT on Linac

Gayou *et al.*: Patient dose and image quality from MV-CBCT Med. Phys. 34 (2), February 2007

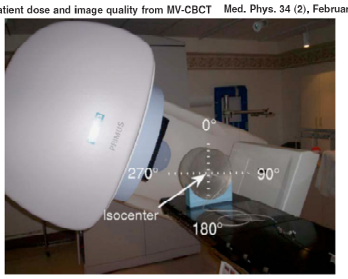


FIG. 1. The cylindrical acrylic phantoms measurement setup. A small volume chamber was placed at the isocenter as well as 1 cm below the surface at the 0°, 90°, 180°, and 270° positions.

Dose from MVCT

Gayou *et al.*: Patient dose and image quality from MV-CBCT Medical Physics, Vol. 34, No. 2, February 2007

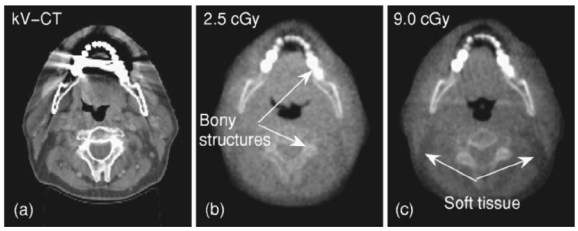


FIG. 8. Transverse slice of a head and neck patient imaged with (a) kV-CT, (b) 2.5 cGy MV-CBCT protocol, (c) 9.0 cGy MV-CBCT protocol. The lower dose is sufficient to show the bony structures on the MV-CBCT image. Soft tissue boundaries are more visible with the higher dose.

Images of MVCT

Sillanpaa *et al.*: Gated megavoltage cone beam CT with aS500 EPID Medical Physics, Vol. 32, No. 3, March 2005

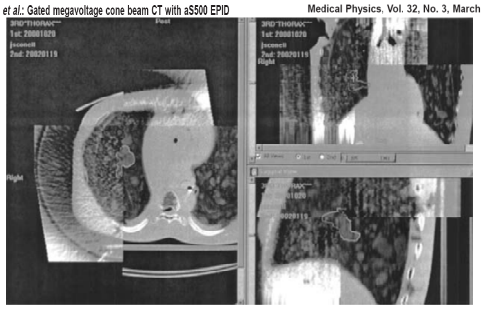


FIG. 12. 20 MU large-field scan registered to a diagnostic CT scan of the same phantom, using a CT-to-CT registration tool. Left: axial view; right upper: coronal view; right lower: sagittal view. MV reconstructions are in the lower-right and upper-left quadrants of each image.

MVCT on Tomo unit

I. J. Radiation Oncology ● Biology ● Physics Volume 56, Number 1, 2003
Image-guided radiotherapy ● T. R. MACKIE *et al.*

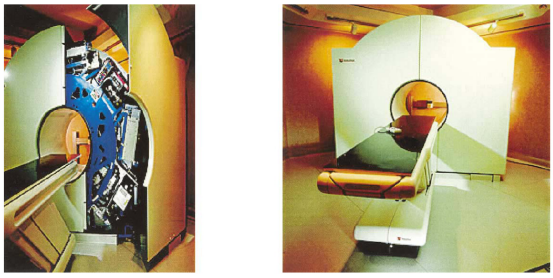
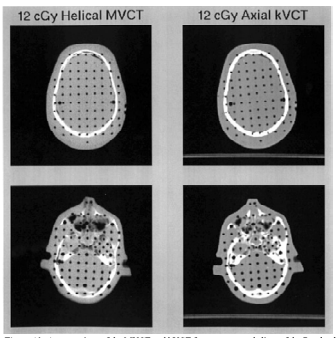


Fig. 3. The helical tomotherapy unit installed at the University of Wisconsin. The left panel is with a cover open. The panel on the right is looking along the CT table into the ring gantry bore.

Dose form MVCT on Tomo unit



K J Ruchala et al
Phys. Med. Biol. **44** (1999) 2597–2621

Figure 10. A comparison of the MVCT and kVCT for reconstructed slices of the Rando phantom.

Dose form MVCT on Tomo unit

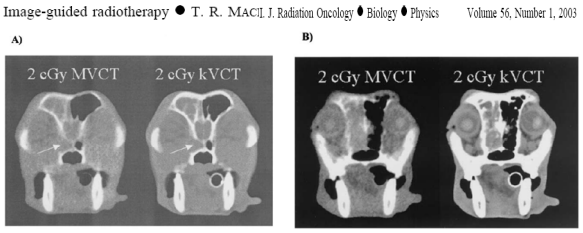
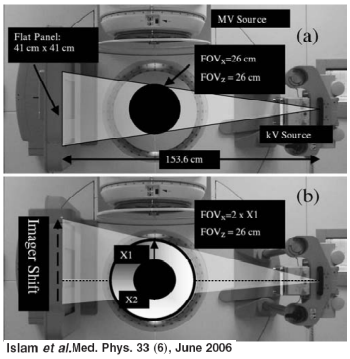


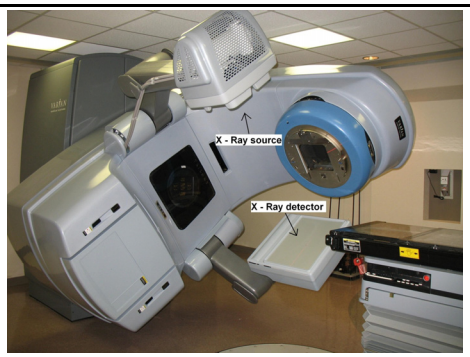
Fig. 4. Comparison of MVCT images to kVCT images. Shown are 2 CT slices from a dog with sarcoma of the sinus. (A) Erosion of the bone is shown with the white arrow. (B) The left sinus is filled with tumor. The MVCT image at 2 cGy does not have sufficient contrast for diagnosis but is sufficient for purposes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

kV x-ray devices on treatment unit



Islam *et al.*Med. Phys. 33 (6), June 2006

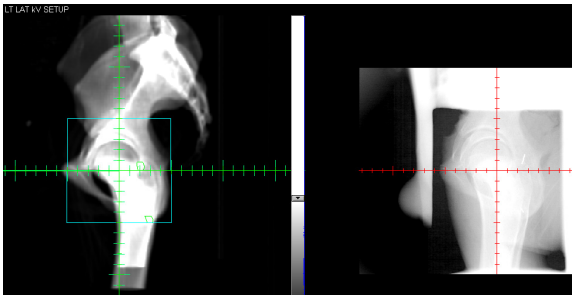
kV x-ray devices on treatment unit



G X Ding *et al* Phys. Med. Biol. **52** (2007) 1595–1615

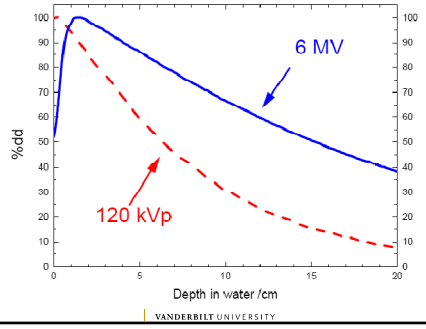
kV x-ray devices on treatment unit

2D images: digital radiograph



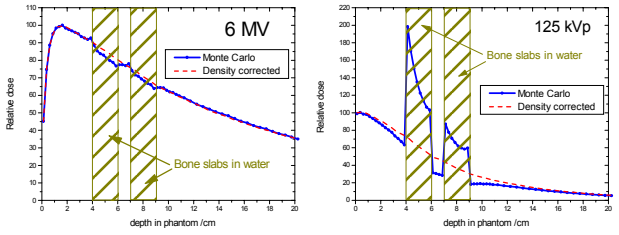
Dose dependency on depth between kV and MV

Single beam incident from right

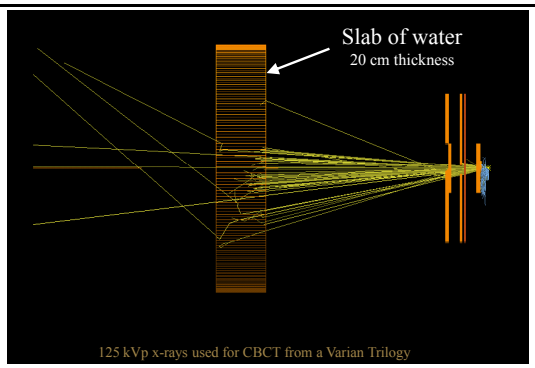


Dose dependency on medium for MV beam

Single beam incident from right

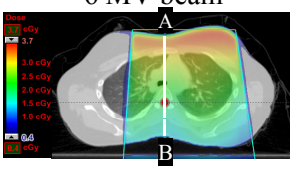


Dose dependency on medium for kV beam

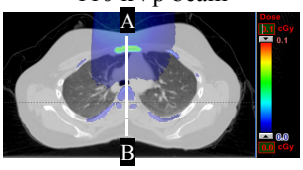


Dose distributions: a single Anterior beam

6 MV beam



110 kVp beam



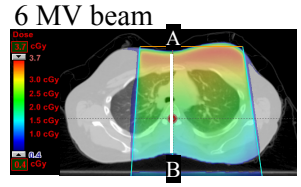
MV: ~ 1- 3 cGy

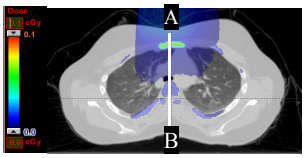
MV: ~ 0.01 cGy

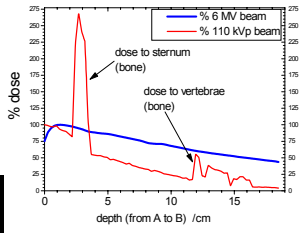
What are the dose profiles along the line AB between MV and kV beams?

Dose distributions: a single Anterior beam

6 MV beam





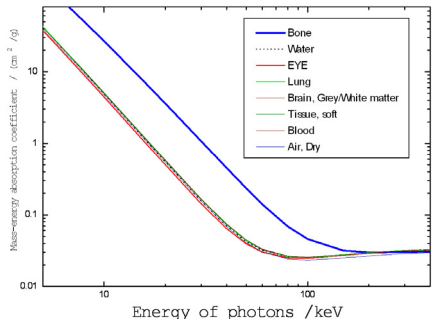


MV: exit dose 40%

kV: exit dose 4%

110 kVp beam

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



Data are from: J. H. Hubbell and S. M. Seltzer, "Tables of X-Ray Mass Attenuation Coefficients and Mass Energy-Absorption Coefficients," National Institute of Standards and Technology, Gaithersburg, MD NISTIR 5632, 1995.

3D images: kV CBCT

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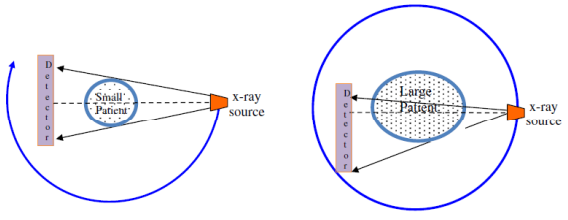

200 degree source rotation and the detector is centered

(a) Full fan type scan

360 degree rotation and the detector is shifted to one side

(b) Half fan type scan

Fig. 1. Illustration of (a) the source rotation range for full fan-type scan in which the X-ray source starts from the patient's left side and ends at 20° past the patient's right side, (b) half fan-type scan in which the X-ray source starts from patient's left side and ends at patient's left side.

Radiation dose dependency on scan techniques: Head

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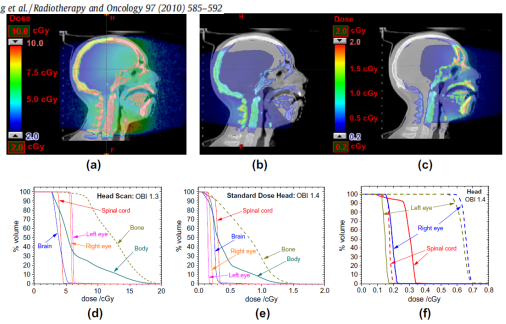

Fig. 2. The OBI 1.3 scan doses are shown in (a) color-wash and (d) dose–volume histogram analysis for specific radiosensitive organs; OBI 1.4 Standard-Dose Head scan doses are shown in (b) and (e). Note that the abscissa in (d) is 10 times larger than in (e). For 200° scans, the effect when rotating the X-ray source below (b) and above (c) the patient is also compared quantitatively in (f).

Radiation dose dependency on scanned length: Pelvis

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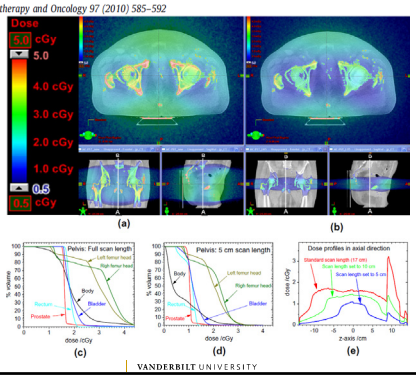

Dose dependency on scan techniques and filters: Pelvis Spot Light

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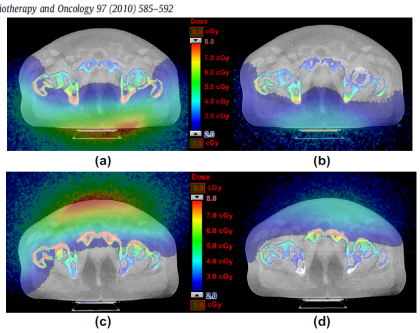

Fig. 4. (a) and (b) Axial view showing dose distributions in color-wash resulting from current Pelvis Spot Light scan with half Bow-tie and with full bow-tie, respectively; (c) and (d) dose distributions in color-wash resulting from OBI 1.4 Pelvis Spot Light scan with half fan bow-tie and with full fan bow tie, respectively. (e), (f), (g) and (h) Corresponding dose–volume histograms for the specific organs.

Dose dependency on scan techniques and filters: Pelvis Spot Light

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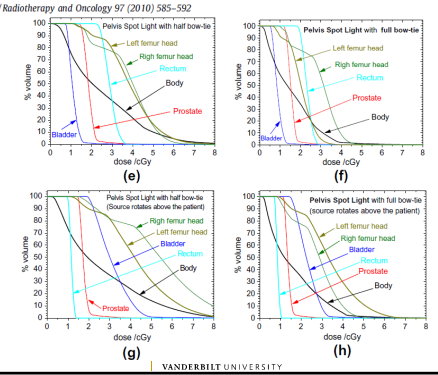
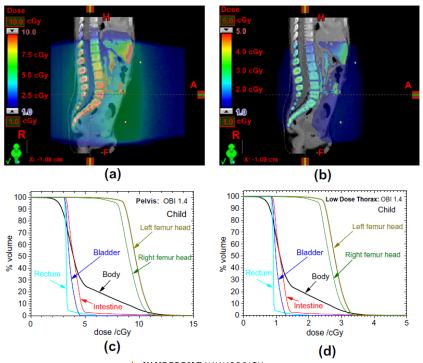
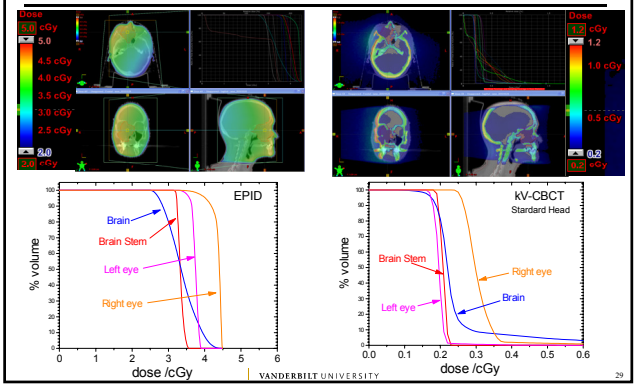


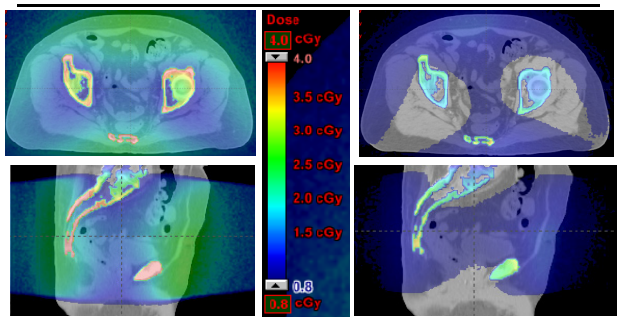
Radiation dose dependency on patient size and scan techniques



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



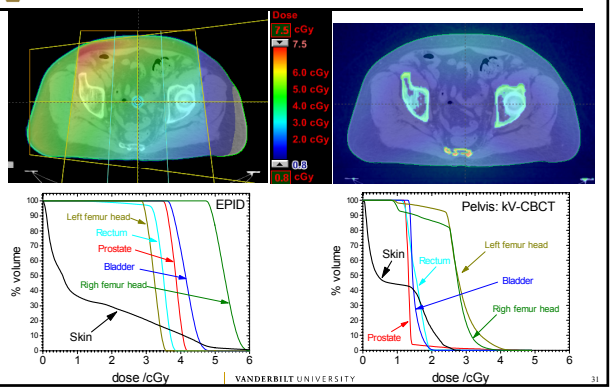
Perspective view: kV CBCT dose continue to decrease



kV-CBCT from Trilogy unit

kV-CBCT from TrueBeam unit

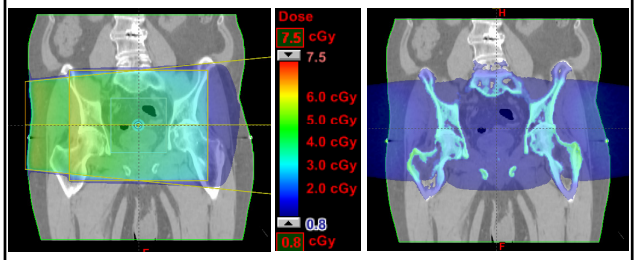
Perspective view: EPID vs. kV-CBCT (Trilogy)



Perspective view: EPID vs. kV-CBCT

4 cGy x 35 Fractions = 140 cGy

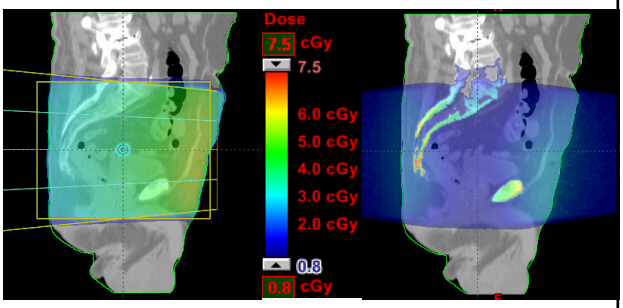
1.5 cGy x 35 Fractions = 52 cGy



EPID
Two 6 MV setup fields

kV-CBCT
from Trilogy unit OBI 1.4

Perspective view: MV orthogonal setup fields dose (2-5 cGy)



Two 6 MV setup fields

kV-CBCT from Trilogy unit

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 factions: 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

- Imaged area is larger than the treatment field
- Imaging-guidance procedures are more frequent than diagnostic imaging
- Repeated imaging procedures can sum up significant dose to radiosensitive organs
- MV EPID imaging: exit dose (~ 50% of entrance dose)
- kV DR imaging: very low dose (also low exit dose ~ 5% of entrance dose)

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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Matthew Deeley,	student at Vanderbilt University
Jason Pawlowski,	student from Vanderbilt University
Charles Coffey,	Vanderbilt University
Arnold Malcolm,	Vanderbilt University
ACCRE	Vanderbilt Advanced Computing Center for Research and Education