

## Accounting for MV Imaging Dose and the Future of MV Imaging



Young Corn, by (Iowan) Grant Wood (1931)

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## Megavoltage Imaging Types and Doses

- Planar MV Imaging with Electronic Portal Imaging Device (multi-vendor)
  - Used for 2-D image guidance
  - Typically acquired weekly (every 5 fractions)
  - Doses of 1-5 cGy, depending on MU per field used
  - Doses  $\leq 1$  cGy per fraction ( $<1\%$  of prescription dose)
  - In this scenario, accounting for dose in the treatment planning process is not necessary



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## Megavoltage Imaging Types and Doses (2)

- Megavoltage Computed Tomography (MVCT), TomoTherapy
  - Used for 3-D image guidance
  - Benefit: Metal artifact reduction relative to kV imaging
  - Benefit: Same source used for treatment and imaging beam
  - Dose typically 1.5 cGy per fraction (max 3.6 cGy)
    - Shah et al, IJROBP 70(5), 1579-87 (2008)
  - Below 5% per fraction => accounting for imaging dose in the treatment planning process not necessary



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### Megavoltage Imaging Types and Doses (3)

- Megavoltage cone beam computed tomography (MV-CBCT), Siemens
  - Used for 3-D image guidance
  - Benefit: Metal artifact reduction relative to kV imaging
  - Benefit: Same EPID/source used for planar and 3-D imaging – less QA to do
  - Doses reported in the literature range from 2-12 cGy
  - Doses site- and protocol-dependent

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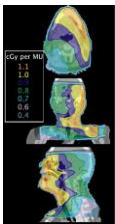
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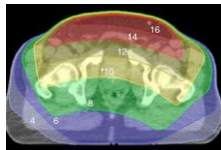
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### Example MV Imaging Doses



Portal imaging doses per MU (0.5 MU for anterior-posterior, 0.5 MU for lateral)  
 Morin et al, Med Phys 34, 1819-1827 (2007)



MV-CBCT: Pelvic dose for 15 MU acquisition  
 • Miften et al, Med Phys 34, 3760-3767 (2007)




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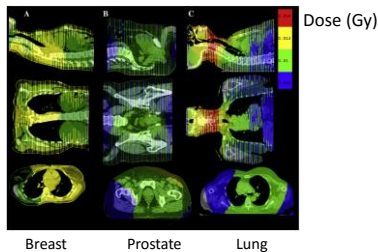
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### Image dose distributions for TomoTherapy MVCT



Shah et al, IJROBP 70, 1579-1587 (2008)

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## Accounting for Imaging Dose in the Treatment Planning Process

- Not necessary for standardly-configured image guidance systems that are currently manufactured.
  - Assumes MV portal imaging is done once a week.
- May be needed for daily MV-CBCT, although MV-CBCT systems are no longer manufactured.
- Daily MV portal imaging at 2 MU per field may justify incorporating imaging dose into the treatment planning process.

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## Methods to Account for MV-CBCT Imaging Dose

- (1) Calculate the dose with the treatment planning system and incorporate it, voxel-by-voxel, into the treatment plan
 

**Advantages:** All dose, for imaging and treatment, is visible in the treatment planning system and reviewable.

**Disadvantages:** Additional time (minute or two) is needed to calculate the imaging dose. Plan checks need to evaluate imaging dose as well.
- (2) Estimate imaging dose using a compiled table or the literature
 

Tables: VanAntwerp et al, Med Dosimetry 36, 284-291 (2011)

**Advantages:** Quick way to determine if imaging dose incorporation is needed

**Disadvantages:** Voxel-by-voxel incorporation not possible, making overall plan evaluation difficult

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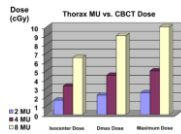
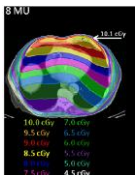
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## MV-CBCT Organ Doses

- Extensive multi-site dose analysis reported by VanAntwerp et al, Med Dosimetry 36, 284-291 (2011)



Organ at Risk	Mean Organ Dose (cGy)	Standard Deviation	Max Organ Dose (cGy)	Standard Deviation
Left lung	1075.2	6.8	0.6	4.2
Right lung	2269.6	6.4	0.5	8.9
Total lung	6225.1	6.6	0.5	9.2
Spinal cord	63.5	4.7	0.8	6.4
Heart	582.9	6.9	1.2	8.8
Vertebral bodies	467.5	4.9	0.6	6.9
Soft tissue	18429.0	4.9	0.7	10.0

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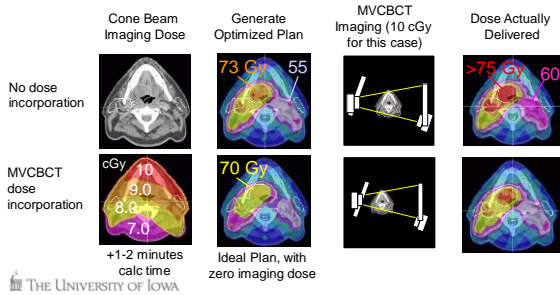
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### MV-CBCT Imaging Dose Incorporation

- Daily MV-CBCT imaging dose calculated for all patients with >5 treatment fractions at the University of Iowa
- 3D-CRT planning:
  - If imaging dose at prescription point is 10 cGy/fx and the desired total dose is 180 cGy, scale treatment beam MUs such that 170 cGy is delivered with treatment beams.
- IMRT planning:
  - Imaging dose is a beam with fixed MUs, and therapeutic beams are optimized "on top of" the imaging dose
    - Miften et al, Med Phys 34, 3760-3767 (2007)
    - Morin et al, Med Phys 34, 1819-1827 (2007)
    - Flynn et al, Med Phys 36, 2181-2192 (2009)



### MV-CBCT treatment planning workflow for IMRT



Imaging dose not incorporated into treatment plan

Imaging dose is incorporated into treatment plan

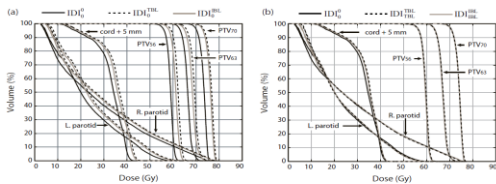
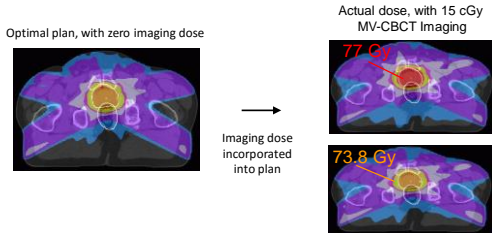


FIG. 10. DVHs for the head and neck case.

Flynn et al, Med Phys 36, 2181-2192 (2009)



## Accounting for MV-CBCT Imaging Dose: Prostate Case



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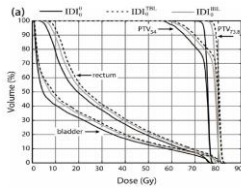
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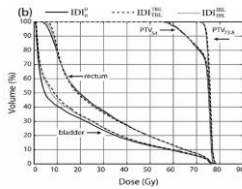
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Imaging dose not incorporated into treatment plan



Imaging dose is incorporated into treatment plan



Flynn et al, Med Phys 36, 2181-2192 (2009)

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## Future of Megavoltage Imaging

- 2-D MV imaging unlikely to go away anytime soon
  - Dose is justifiable given the low magnitude and benefits
  - For large patients, 2-D kV images may be of poor quality
- TomoTherapy MVCT imaging dose is reasonable and does not need to be incorporated into treatment plans.
  - 500 TomoTherapy units worldwide (confirmed by Accuray)
- Extent of MV-CBCT usage is unknown – product no longer sold by Siemens or any other vendor. End-of-life assumed to be 2022 – 10 years after end of manufacturing.
- Varian has a 2.5 MV imaging beam product for TrueBeam 2.0
- Could MV imaging be used to complement kV imaging?
  - Xu et al, Med Phys 41, 146 (2014)

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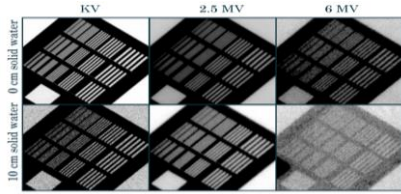
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### Varian 2.5 MV Imaging Beam



Song et al, AAPM Meeting, 2014

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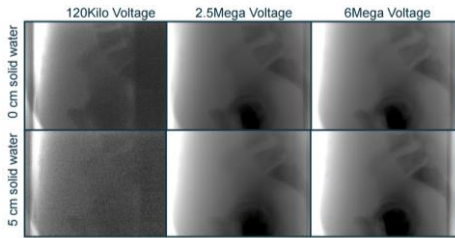
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### Varian 2.5 MV Imaging Beam



Song et al, AAPM Meeting, 2014

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### 2-D Imaging Analysis with the Varian 2.5 MV beam

Nitsch P, Robertson D, Balter P, Med Phys 42, 3266 (2015)

- TrueBeam 2.0 2.5 MV imaging beam, kV, and 6 MV image quality and dose metrics were compared.
- Dose lower for 2.5 MV than for 6 MV
- SNR: Best for kV, then 2.5 MV, then 6 MV
- Conclusions: kV images provide best image quality per unit dose
- The 2.5 MV beam had excellent contrast at a lower dose than 6 MV and may be superior to kV for difficult to image areas that include large changes in anatomical thickness.

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## Conclusions

- Doses for MV-CBCT imaging can be high enough that imaging dose incorporation may be needed
- Imaging dose incorporation is achievable with commercially-available treatment planning systems.
- The future of MV-CBCT is questionable. The modality appears to be nearing obsolescence.
- 2.5 MV beams for imaging are emerging and commercially available.

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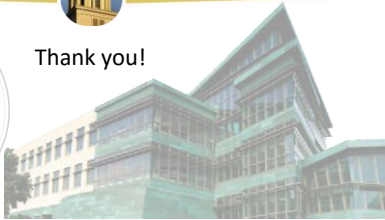
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Thank you!



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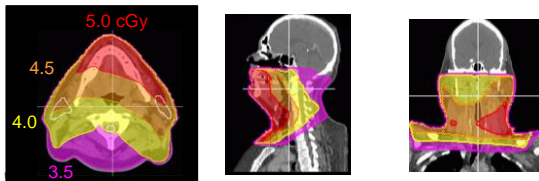
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## Treatment beam MVCBCT imaging dose

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Head and neck case



Prostate case

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### To do

- Ask Varian if any plans are in place for MV-CBCT with the 2.5 MV beam available on TrueBeam. (Asked John Yasenak 7/12/16)
- Ask Siemens how many Oncors remain worldwide with MV-CBCT capabilities. (Asked Lucas 7/12/16)
- Ask Elekta if they have any plans to release an MV-CBCT system (Asked Kevin Brown 7/12/16)
- Confirm the number of TomoTherapy systems worldwide. Guessing 600. (Called Chris Thomes at Accuray on 7/12/16)

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### Question 1

- What is the expected MVCT (TomoTherapy) dose range?
  - (a) 0.03 – 0.1 cGy
  - (b) 0.3 – 1 cGy
  - (c) 3 – 10 cGy
- Answer: (b)
- Reference: Meeks et al, Med Phys 32, 2673-81 (2005)

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### Question 2

- What is a typical MV-CBCT dose to isocenter for a pelvic cancer patient?
- (a) 0.01 cGy
  - (b) 0.1 cGy
  - (c) 1 cGy
  - (d) 10 cGy
  - (e) 100 cGy

Answer: (d)  
Reference: Miften et al, Med Phys 34, 3760-3767 (2007)

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### Treatment Planning Systems Capable of Image Dose Incorporation

- CMS XiO: Yes
  - Miften et al, Med Phys 34, 3760-3767 (2007)
- Pinnacle: Yes
  - Morin et al, Med Phys 34, 1819-1827 (2007)
  - Flynn et al, Med Phys 36, 2181-2192 (2009)
- Eclipse: Not sure
- Monaco: Not sure
- RayStation: Not sure

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