Confining radiation dose for dual energy stereoscopic x-ray imaging

Mike Sattarivand

PhD, MCCPM, ABR, PEng, CRPA(R)

June 2017

Outline

- Introduction
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- Dose measurement methods
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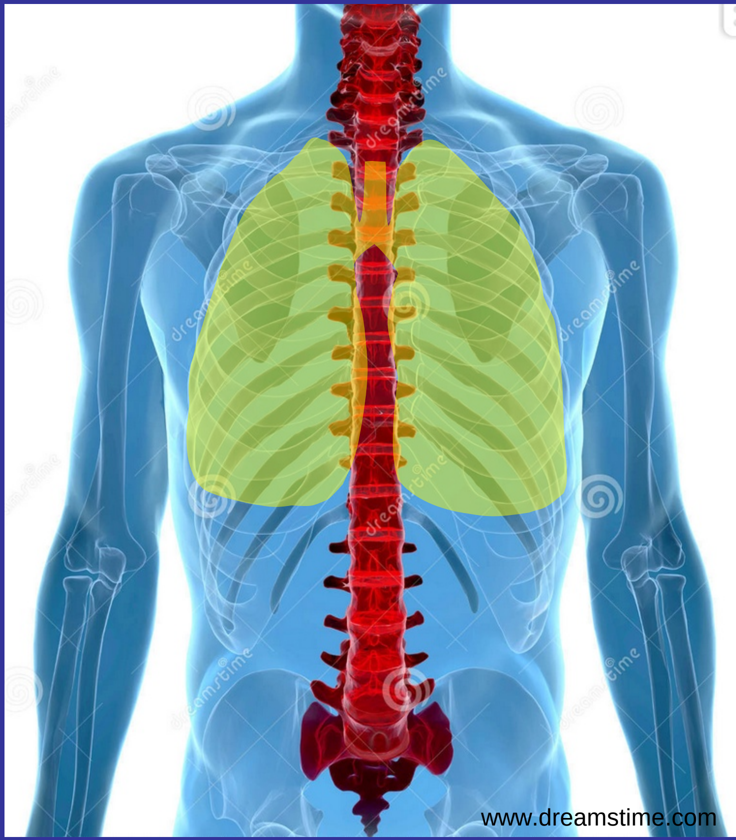
  - Dual energy imaging of a phantom
- Conclusion

Stereotactic body radiation therapy (SBRT)

Precise delivery of highly conformal hypo-fractionation (extra-cranial)

- Early stage lung cancer[1]
- Extra-cranial metastasis (lung, spine)[2,3]

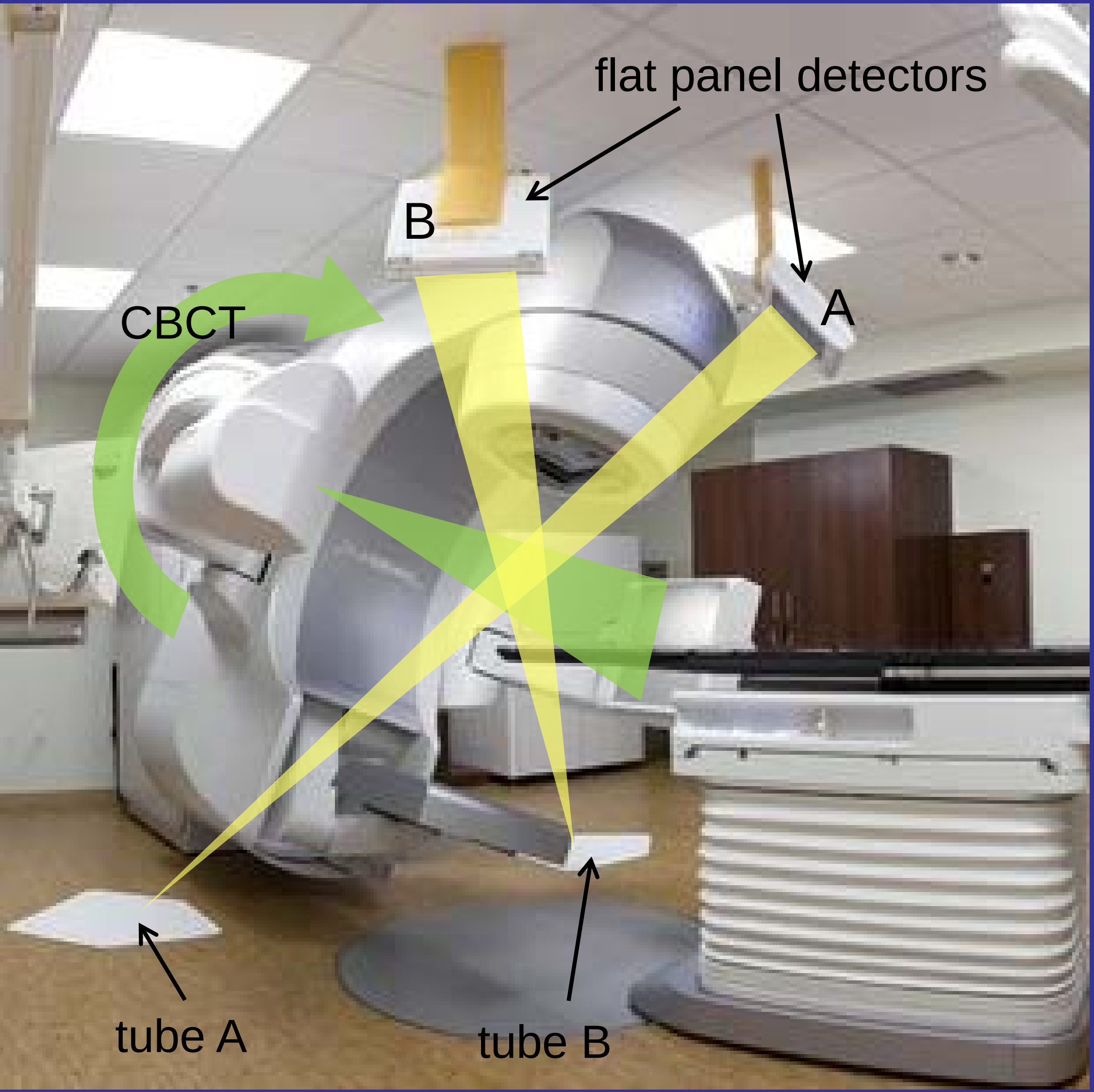


Accuracy: Fundamental requirement
(high doses, limited fractions)

⇒ Image guidance

1.Timmerman (2010) AMA 2.Dahele (2011) Can.J.Neurol.Sci. 3.Lo (2010) Nat.Rev.Clin.Oncol.

Image guidance



CBCT:

✓ Volumetric

→ Slow

→ Tx interruption

Stereoscopic (ExacTrac):

3D info from 2 x 2D

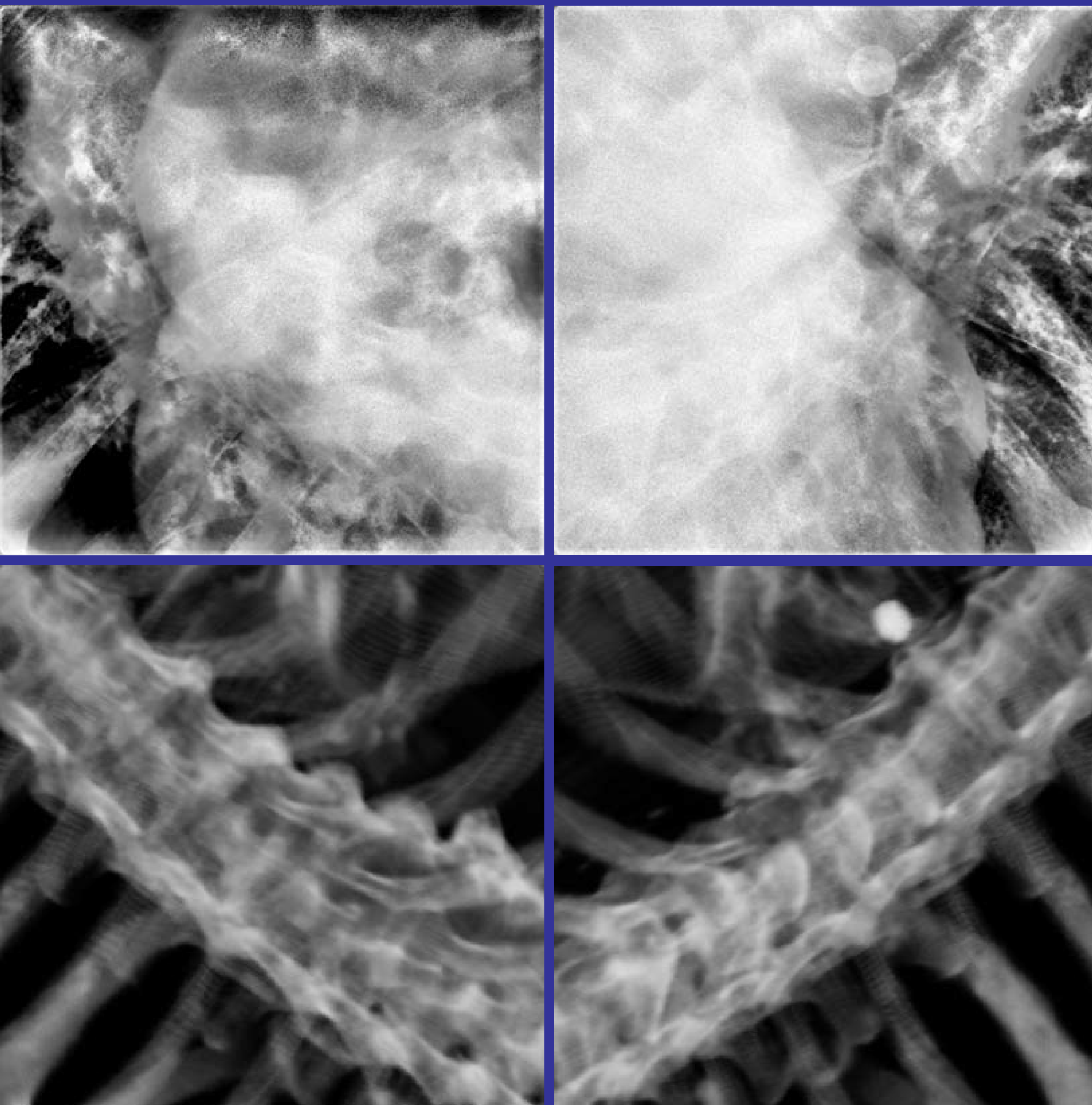
✓ Fast acquisition, processing

✓ Finer resolution

✓ Low dose

→ Tissue overlap

Tissue overlap problem



✓ see bone/tumor in ref images

X cannot see in stereoscopic

Lung: Bone overlap

Spine: Soft tissue overlap

Remove “anatomical noise” ?

soft - tissue - only - image

bone - only - image

Dual energy imaging

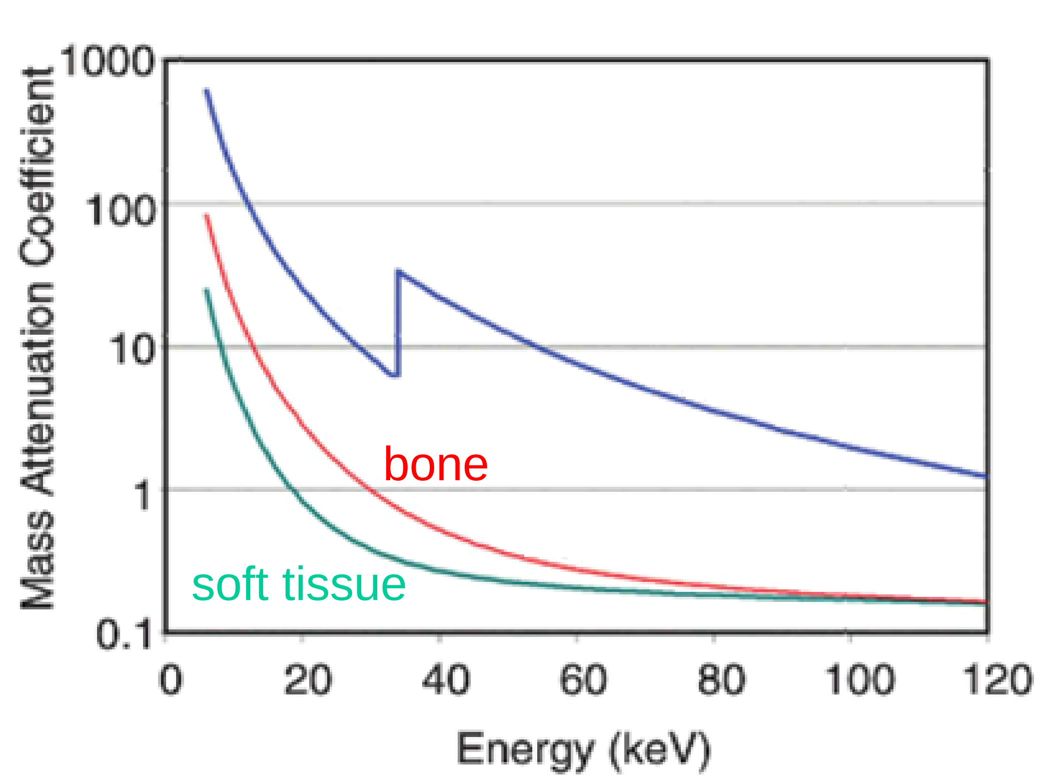
Different material → different attenuation (energy dependent)

- Take 2 images:
  - HE: High Energy (ρ)
  - LE: Low Energy (ρ , Z)

- Weighed subtraction:

$$\ln(HE) - \omega_t \ln(LE) = \text{soft-tissue-only}$$

$$-\ln(HE) + \omega_b \ln(LE) = \text{bone-only}$$



Bushberg (2012) 3rd ed

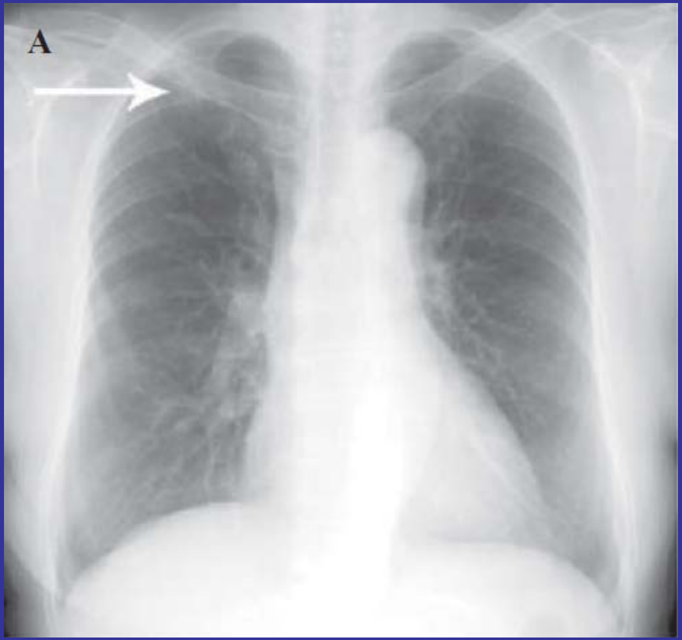
Dual energy: Material identification

Airport security

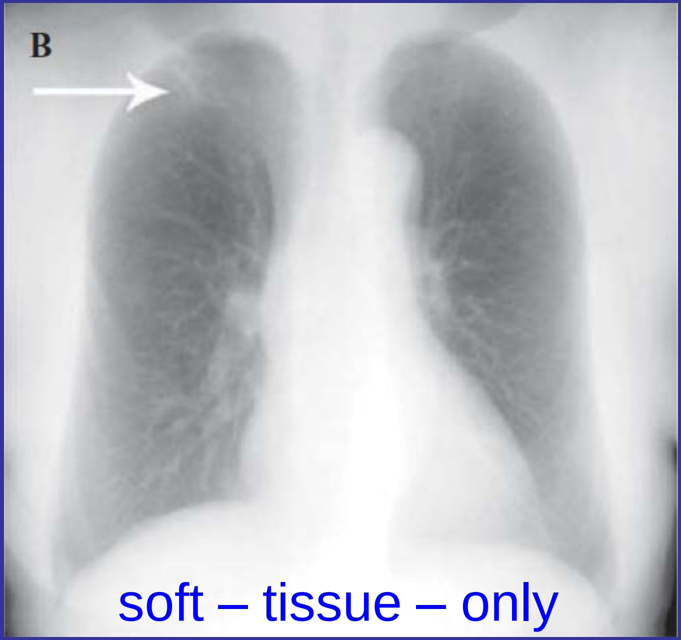
HE: High Energy (ρ)
LE: Low Energy (ρ , Z)

Rebuffel (2006) ECNDT

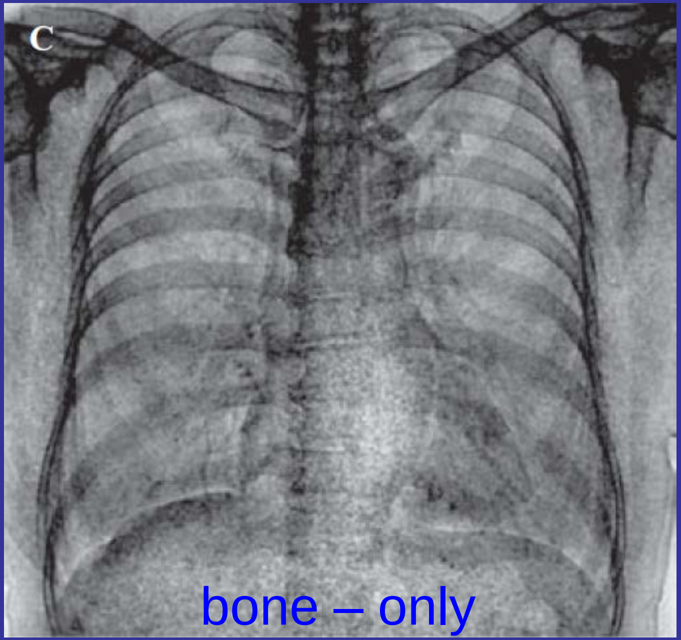
Dual energy: Chest radiography



Conventional Clinical
Single Energy (SE)



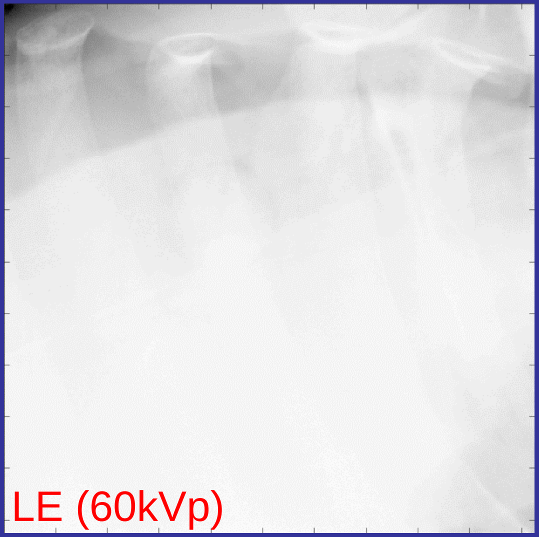
Dual Energy (DE)

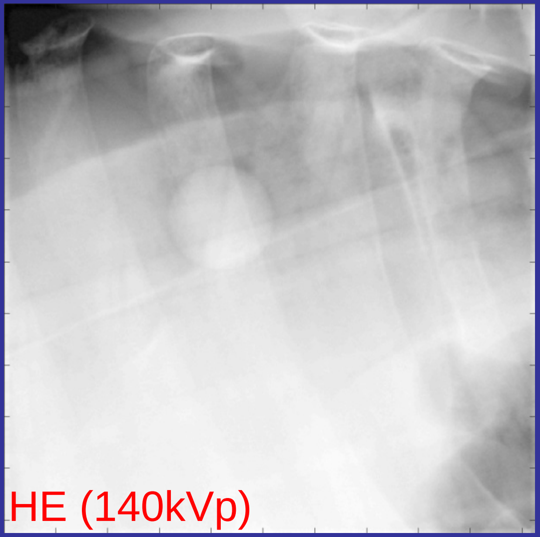


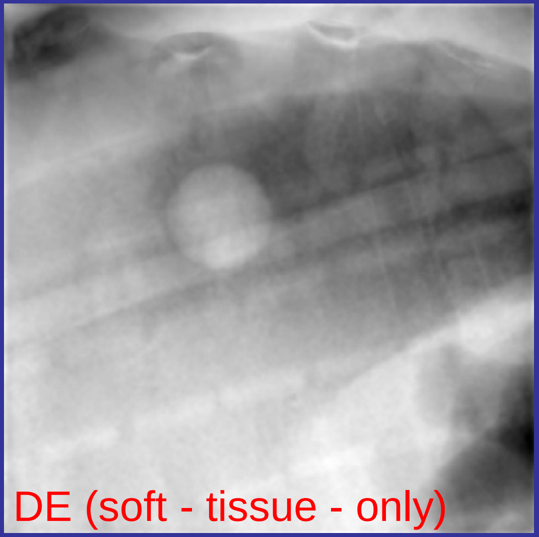
Ide (2006) Radiat Med

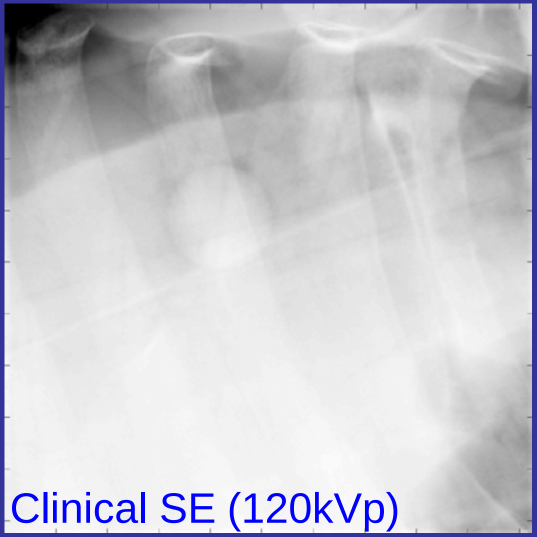
Dual energy: Why confine dose?

$\text{Dose}_{LE} + \text{Dose}_{HE} = \text{Dose}_{DE}$ $\Rightarrow$ dose accumulation









$$\text{Dose}_{DE} \leq \text{Dose}_{SE}$$

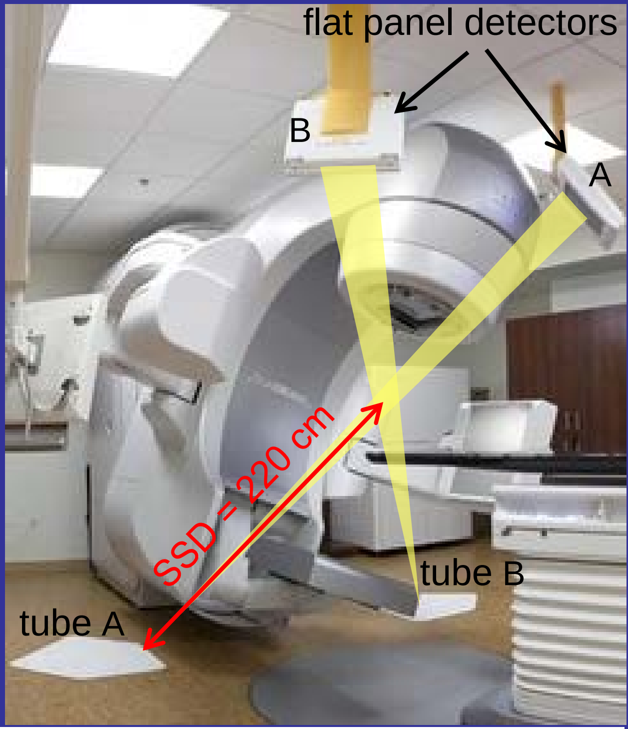
Objective

1. To measure dose for stereoscopic imaging and

2. To confine dose for dual energy (DE) such that dose is ≤ than that of clinical single energy (SE) imaging.

Methods: Dose measurement (TG61)

$$\underbrace{D_{w,z=0}}_{\text{surface dose}} = \underbrace{A}_{\text{air kerma RaySafe detector}} \cdot \overbrace{B_w}^{\text{backscatter factor}} \cdot \underbrace{\left[\left(\frac{\overline{\mu}_{en}}{\rho}\right)_{air}^{w}\right]}_{\text{mass energy-absorption coefficient}}$$



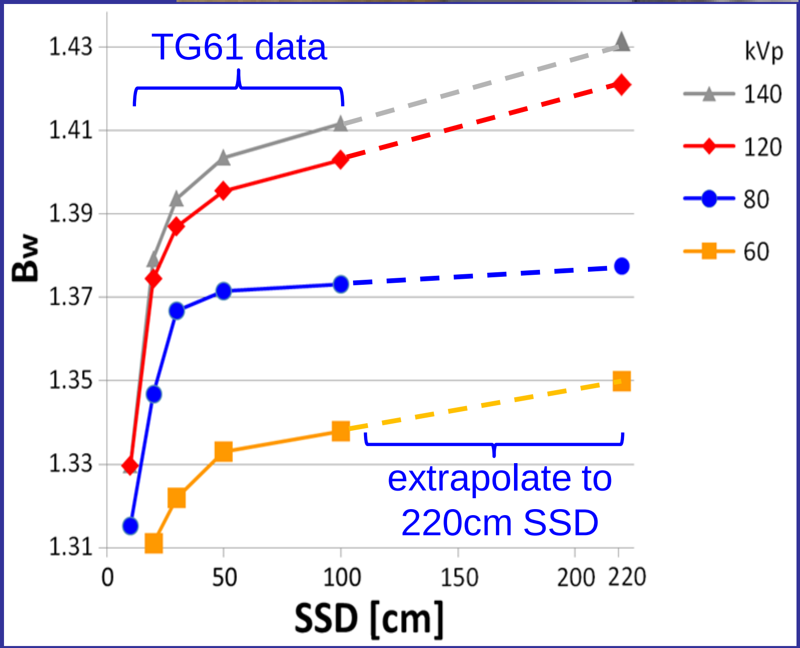
HVL measured using the RaySafe detector

$$\text{kVp} = [\underbrace{60, \ldots 80}_{\text{LE}}, \underbrace{120 \ldots 140}_{\text{HE}}]$$

Tin filter [0, 0.7] mm

mAs varied such that dose $_{DE}$ ≤ dose $_{SE}$

Dose $_{DE}$ = Dose $_{LE}$ (30%) + Dose $_{HE}$ (70%)

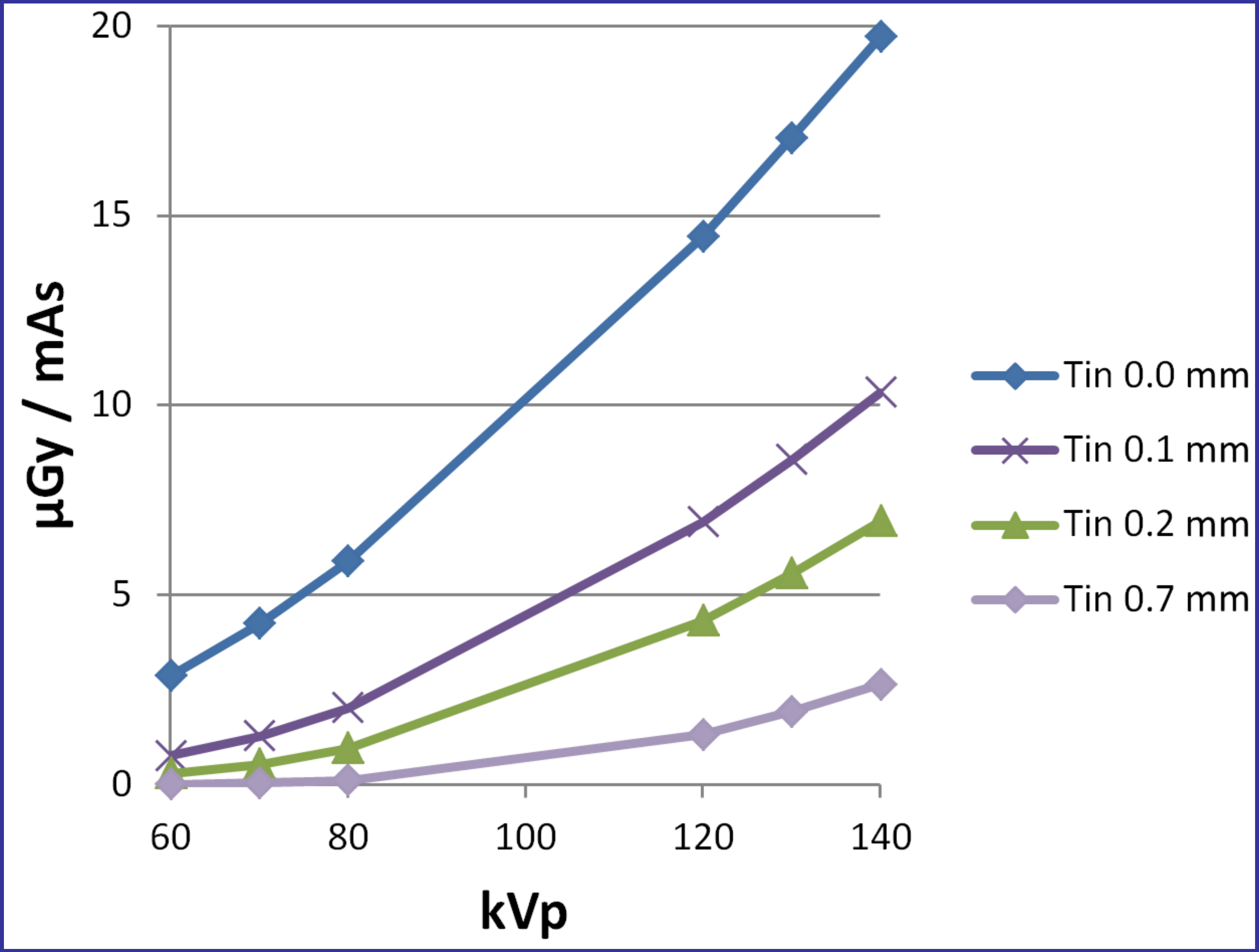


Methods: Physical phantom experiment

Implemented a sphere tumor model in the lung of a Rando phantom
Acquired SE & DE images
Calculate DE images in Matlab

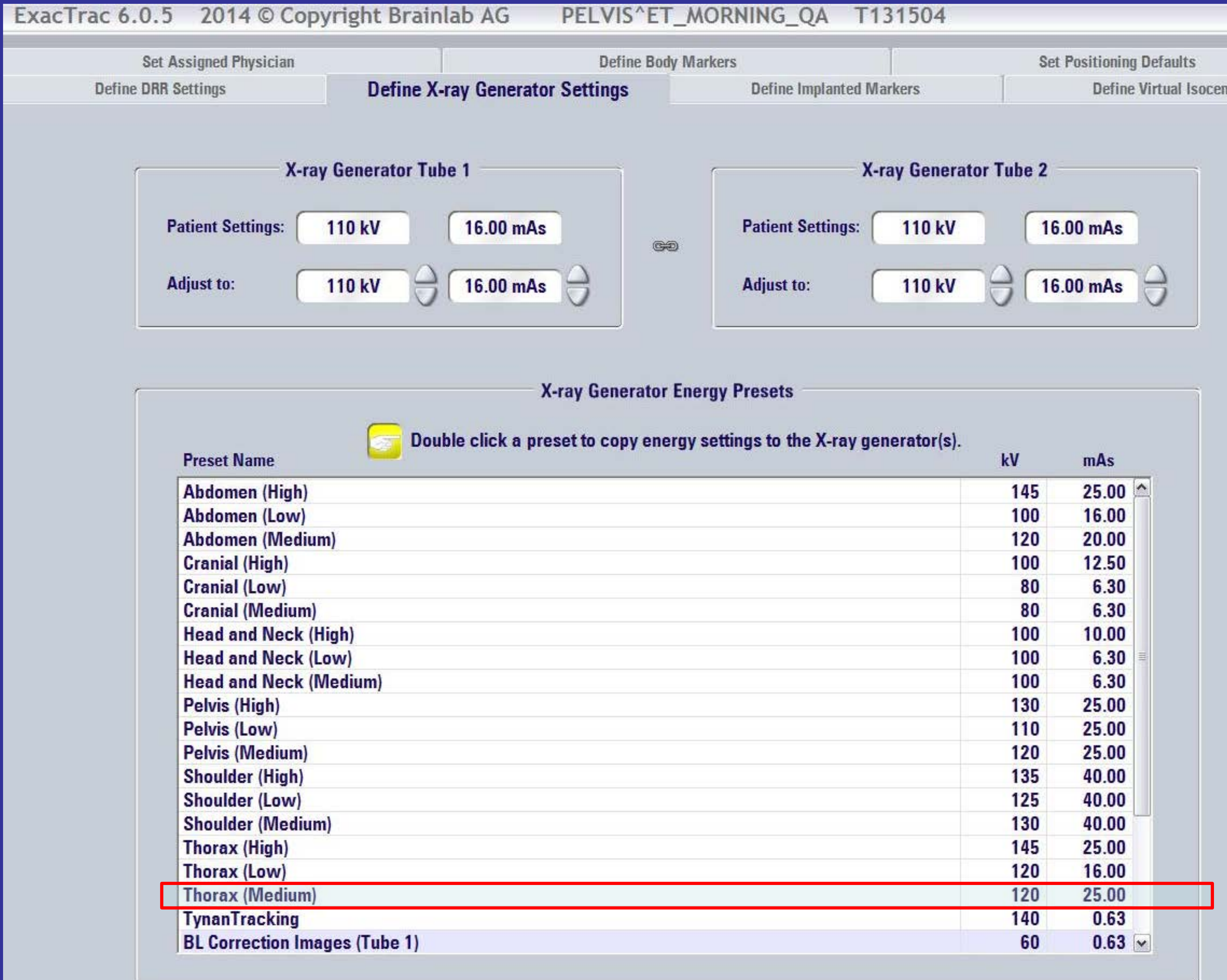
Bowman (2017) Med Phys

Results: Air kerma



⇒ Can calculate patient dose of any given imaging protocol

Results: Patient dose – Clinical single energy



ExacTrac 6.0.5 2014 © Copyright Brainlab AG PELVIS^ET_MORNING_QA T131504

Set Assigned Physician | Define Body Markers | Set Positioning Defaults

Define DRR Settings | **Define X-ray Generator Settings** | Define Implanted Markers | Define Virtual Isocente

X-ray Generator Tube 1

Patient Settings: 110 kV 16.00 mAs

Adjust to: 110 kV 16.00 mAs

X-ray Generator Tube 2

Patient Settings: 110 kV 16.00 mAs

Adjust to: 110 kV 16.00 mAs

X-ray Generator Energy Presets

Double click a preset to copy energy settings to the X-ray generator(s).

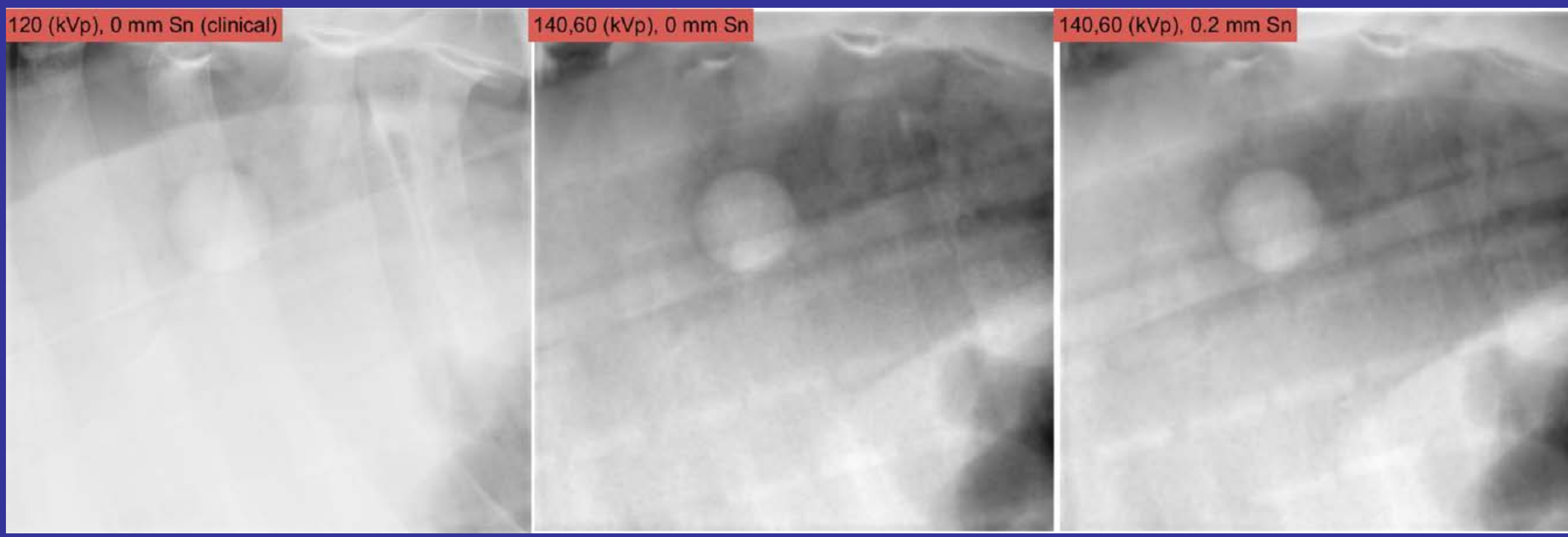
Preset Name	kV	mAs
Abdomen (High)	145	25.00
Abdomen (Low)	100	16.00
Abdomen (Medium)	120	20.00
Cranial (High)	100	12.50
Cranial (Low)	80	6.30
Cranial (Medium)	80	6.30
Head and Neck (High)	100	10.00
Head and Neck (Low)	100	6.30
Head and Neck (Medium)	100	6.30
Pelvis (High)	130	25.00
Pelvis (Low)	110	25.00
Pelvis (Medium)	120	25.00
Shoulder (High)	135	40.00
Shoulder (Low)	125	40.00
Shoulder (Medium)	130	40.00
Thorax (High)	145	25.00
Thorax (Low)	120	16.00
Thorax (Medium)	120	25.00
TynanTracking	140	0.63
BL Correction Images (Tube 1)	60	0.63

Dose
0.52 mGy

Results: Patient dose – Rando phantom

Dual-energy

Single energy



mAs	25	40 (LE) 12 (HE)	347 (LE) 40 (HE)
Dose [mGy]	0.52	0.52	0.52

Bowman (2017) Med Phys

Conclusion

- Patient dose was measured and fully characterized for both clinical SE and DE imaging as a function of tube mAs, kVp, and tin filtration.

- DE imaging parameters were optimized and mAs values varied such that DE imaging dose is confined to the clinical single dose of 0.52 mGy.

Acknowledgments

Contribution from:

- Dr. James Robar
- Wesley Bowman
- Ian Porter (machine shop)
- Angela Henry
- NSHA therapists

Funding:

BrainLAB

nova scotia health authority