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Evaluation of intraoperative imaging alternatives for IOERT

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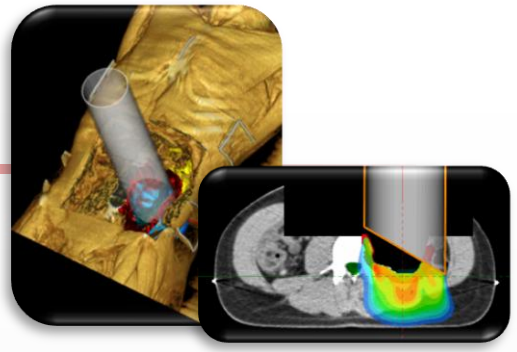
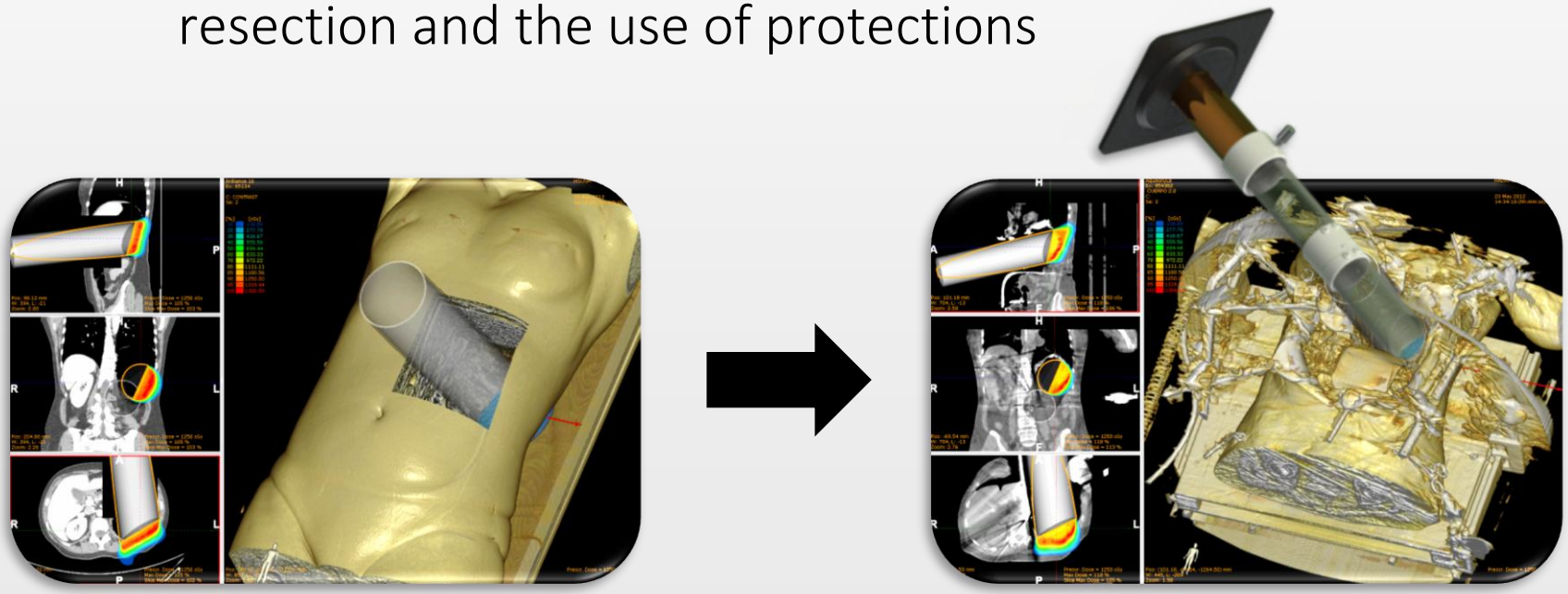
INTRAOPERATIVE RADIATION THERAPY

IOERT dose distribution (I)

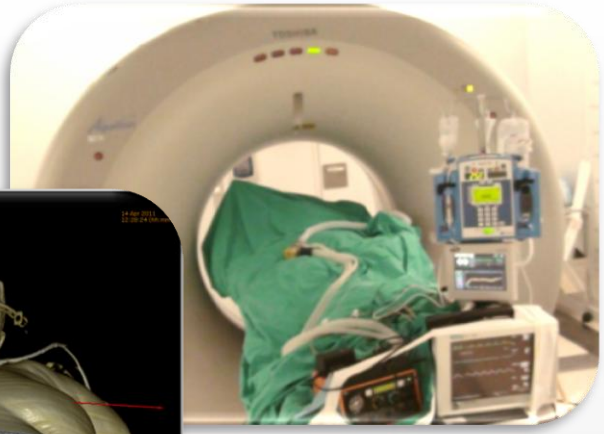


- Dosimetric planning (radiance,)
  - Radiation attenuation for each tissue type estimated from CT values → Preoperative CT image
- Real treatment
  - Retraction and displacement of structures, tumor resection and the use of protections

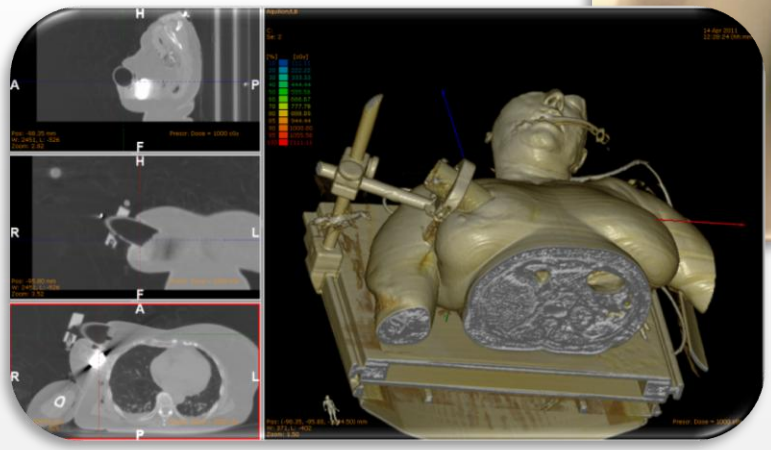


IOERT dose distribution (II)

- Intraoperative imaging?



CT images



- **Objective**
  - Evaluate the image quality offered by different CT devices when they are used to estimate dose distribution for IOERT procedures

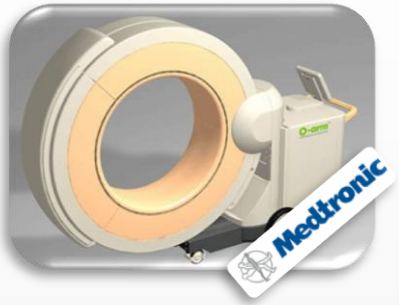
Materials and Methods (I)

CT simulator

- **Gold standard**
- Aquilion/LB
- **Multi-slice helical CT** (16 slices)
- FOV 70 cm
- Gantry aperture 90 cm

versus

≈ C-ARM



- O-ARM
- **CBCT**
- FOV Ø 20 cm x 15 cm
- Gantry aperture 96.5 cm

KVCT + LINAC

- TrueBeam
- **CBCT**
- FOV 46 cm x 46 cm x 16 cm
- Distance source-detector: 150 cm

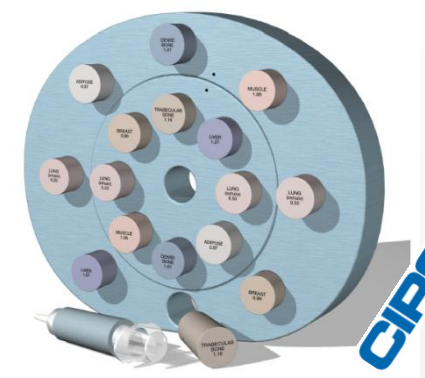
Mobile CT

- BodyTom
- Mobile CT
- **32 slice CT scanner**
- FOV 60 cm
- Gantry aperture 85 cm

Materials and Methods (II)

- Phantoms

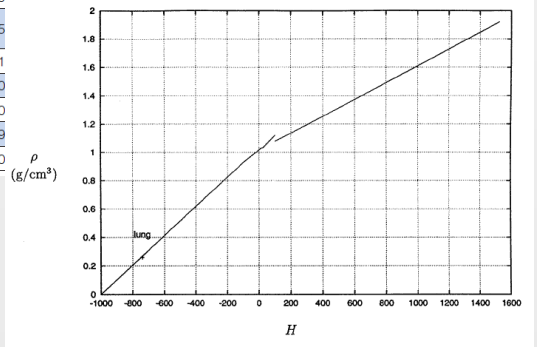
Model 062



Model 062 Includes

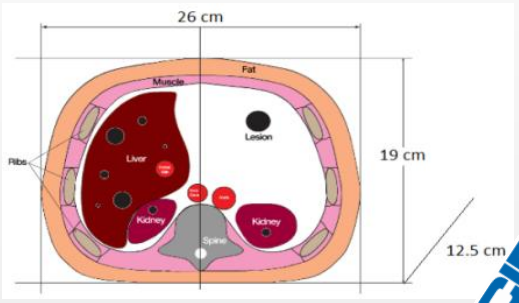
Quantity	Model No.	Description	Physical Density	Electron Density Per cc x 10^{23}	RED (Relative to H_2O)
1	06202	PHANTOM HEAD (Center Section)	1.01	3.346	1.002
1		PHANTOM BODY (Outer Ring)	1.01	3.346	1.002
INSERTS					
1	06203	H_2O SYRINGE	1.00	3.340	1.000
2	06204	Lung (Inhale)	0.20	0.634	0.190
2	06205	Lung (Exhale)	0.50	1.632	0.489
2	06206	Breast (50/50)	0.99	3.261	0.976
2	06207	*Dense Bone 800mg/cc (Embedded)	1.5		
2	06208	Trabecular Bone 200mg/cc	1.1		
2	06209	Liver	1.0		
2	06210	Muscle	1.0		
2	06211	Adipose	0.9		
2	06213	Distance Marker	1.0		

33 cm x 27 cm x 5 cm

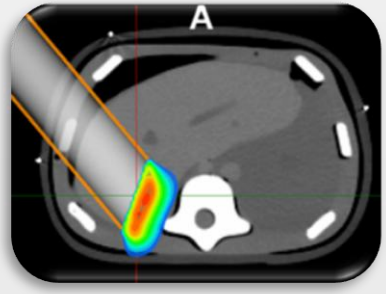


Schneider et al, Phys. Med. Biol. 1996

Model 057

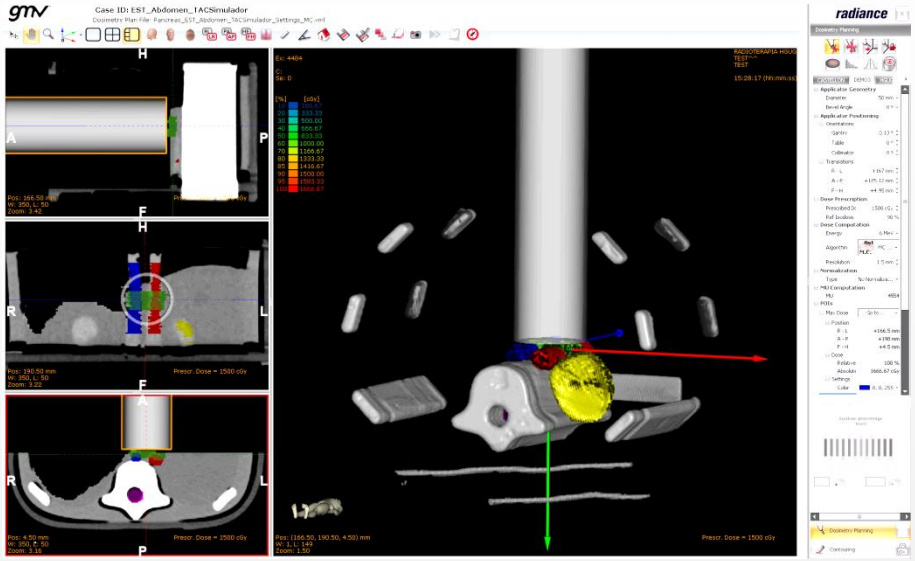


26 cm x 19 cm x 12.5 cm



Materials and Methods (III)

- IOERT case

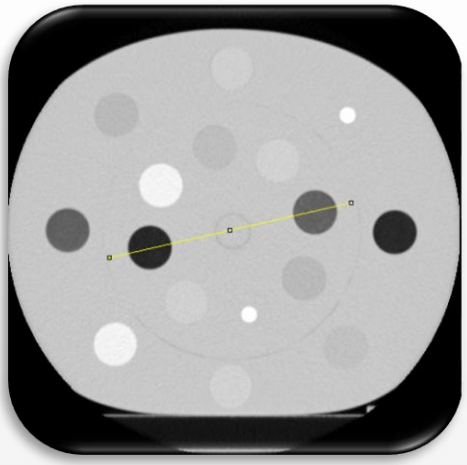


Case 1: Tumour in Pancreas
(50 mm, 0°, 15 Gy)

- Comparison
  - CT-to-density conversion curves, Profiles
  - Cumulative dose-volume histograms, Percentage Depth Doses (PDDs), Transverse beam profiles, Gamma criterion → **radiance**

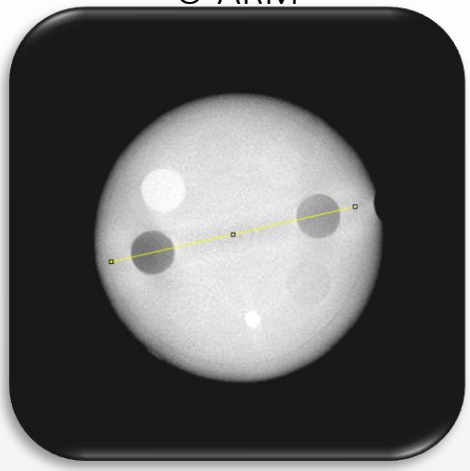
Results: Profiles

CT simulator



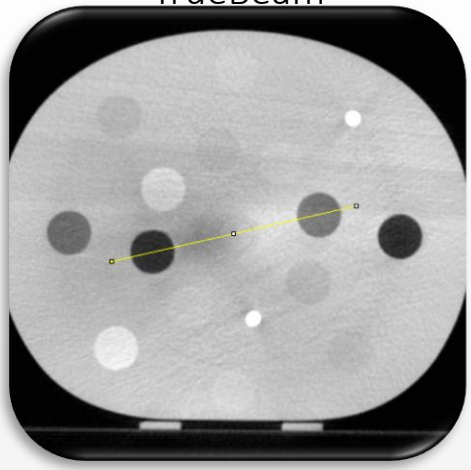
120 kV, 300 mAs

O-ARM



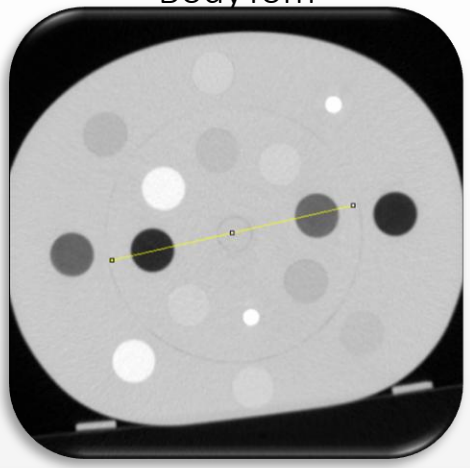
120 kV, 298 mAs

TrueBeam



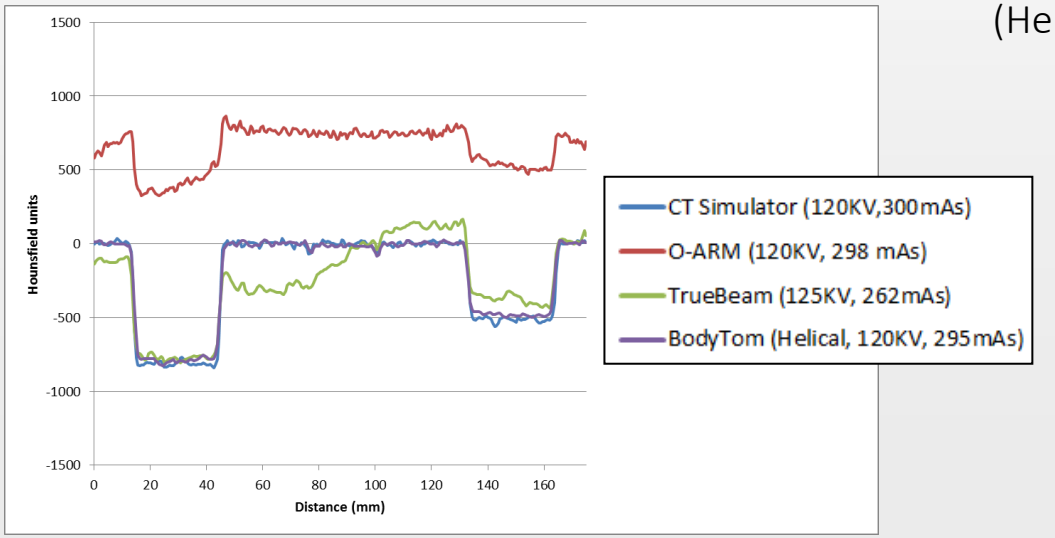
125 kV, 262 mAs

BodyTom

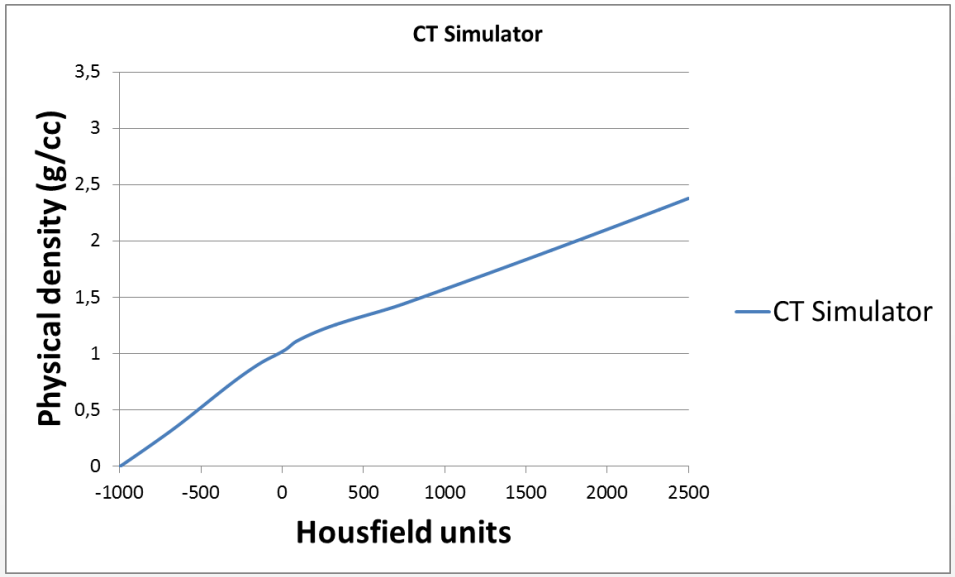


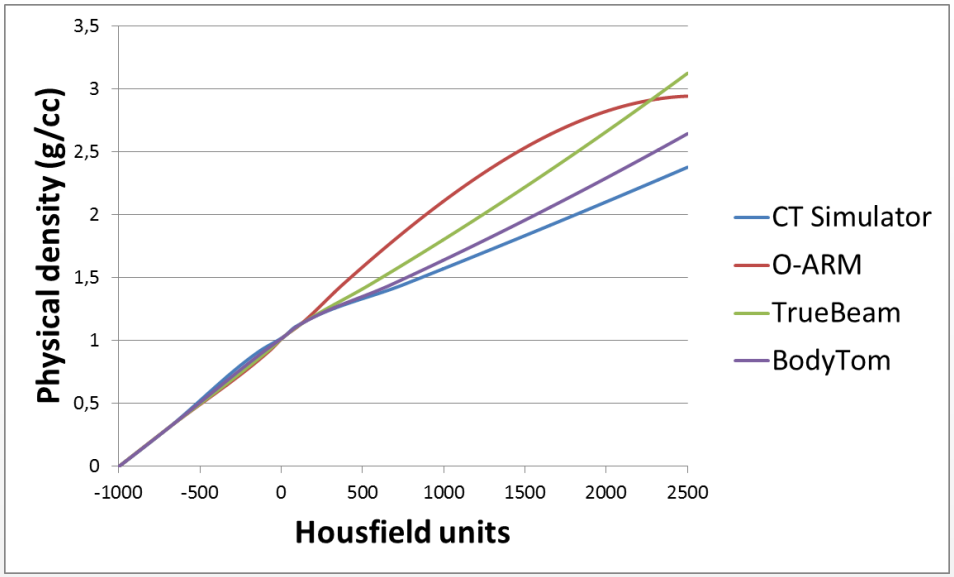
120 kV, 295 mAs (Helical)

Lung inhale
Water
Lung exhale

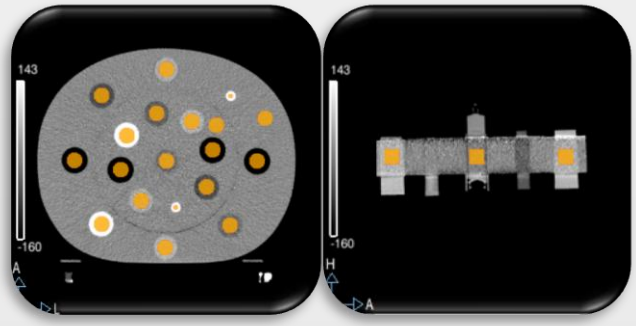


Results: CT-to-density conversion curve

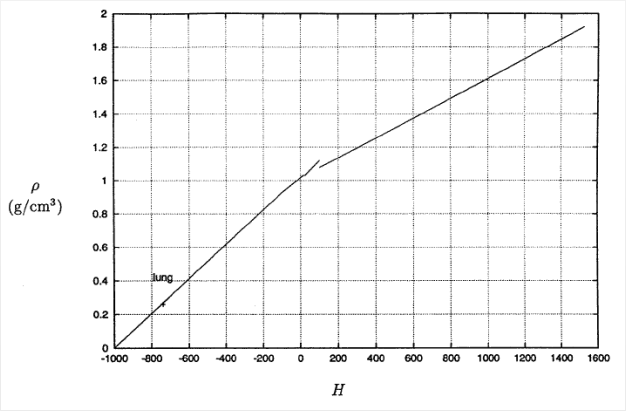




O-ARM adjustment → air to -1000 HU and water to 0 HU
Stoichiometric calibration*



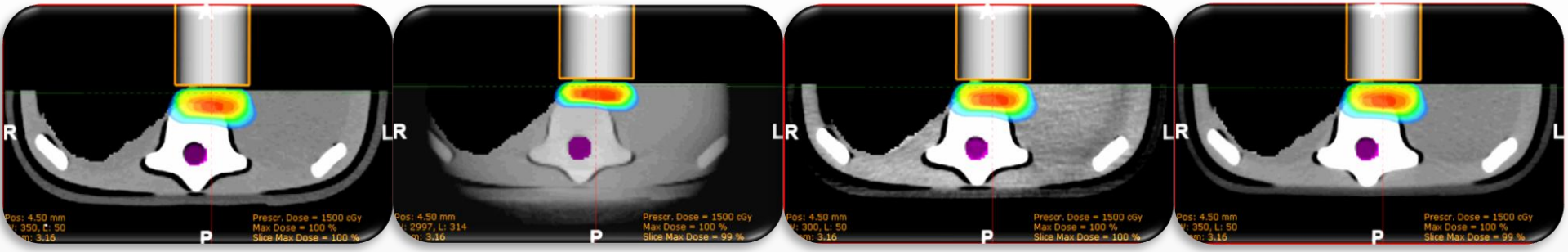
Plugs → 35 cc
ROIs → 6.3 cc
Dense bone → 0.5 cc



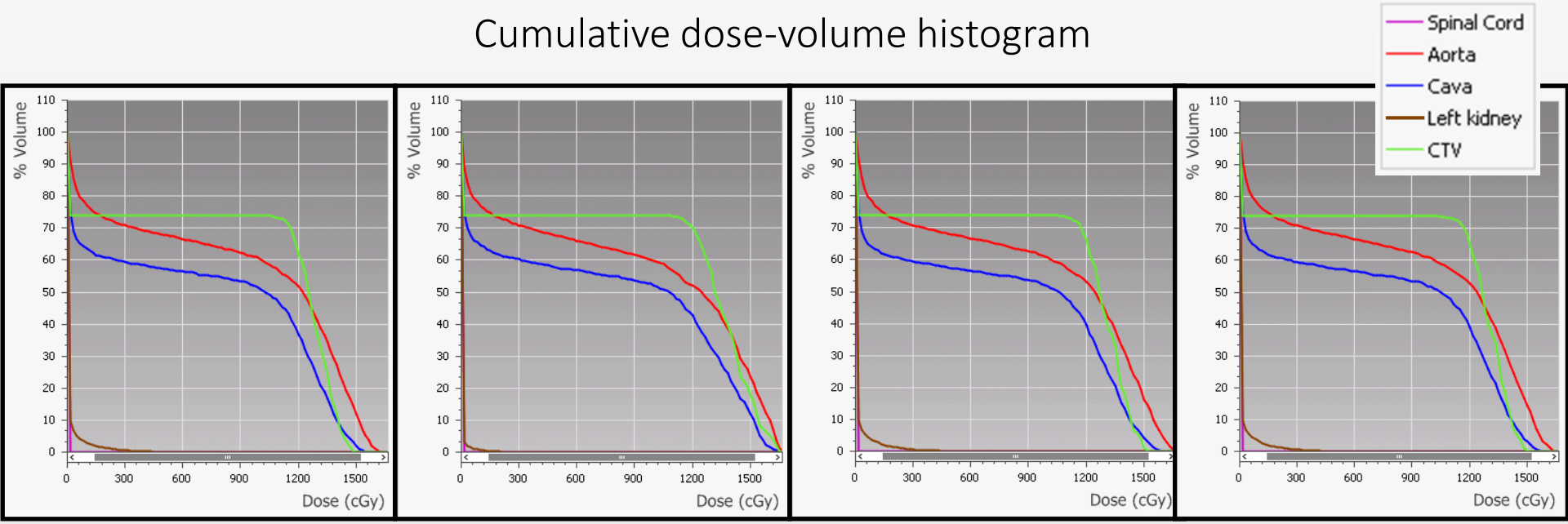
(*) Schneider et al, Phys. Med. Biol. 1996

Results: Pancreas (I)

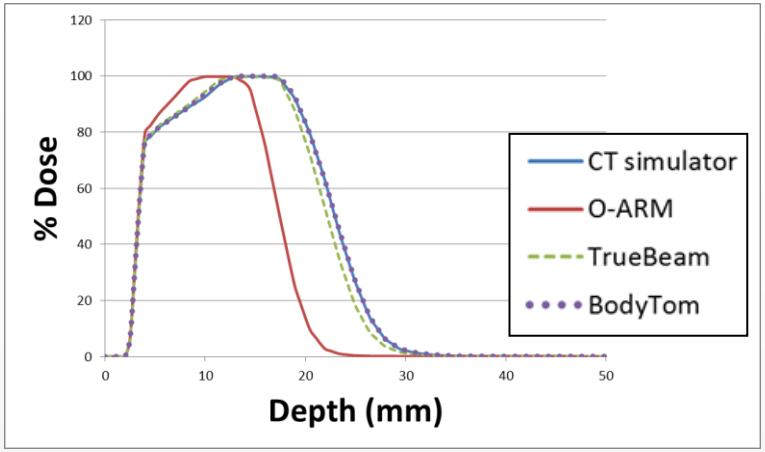
CT simulator | O-ARM | TrueBeam | BodyTom



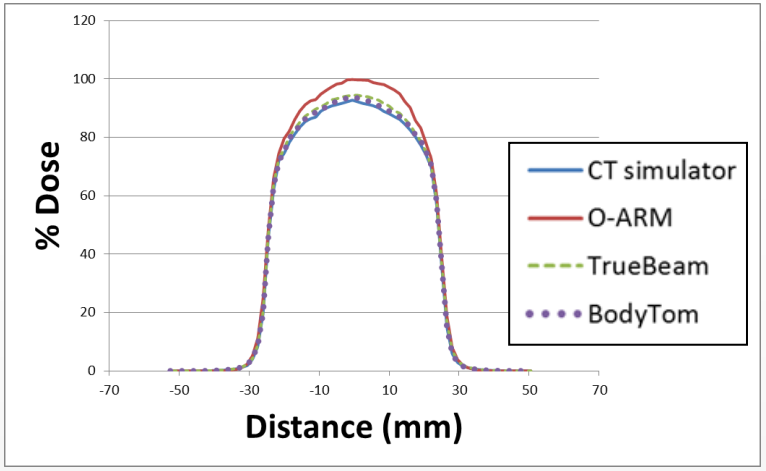
Cumulative dose-volume histogram



Results: Pancreas (II)



Percentage Depth Dose (PDD)

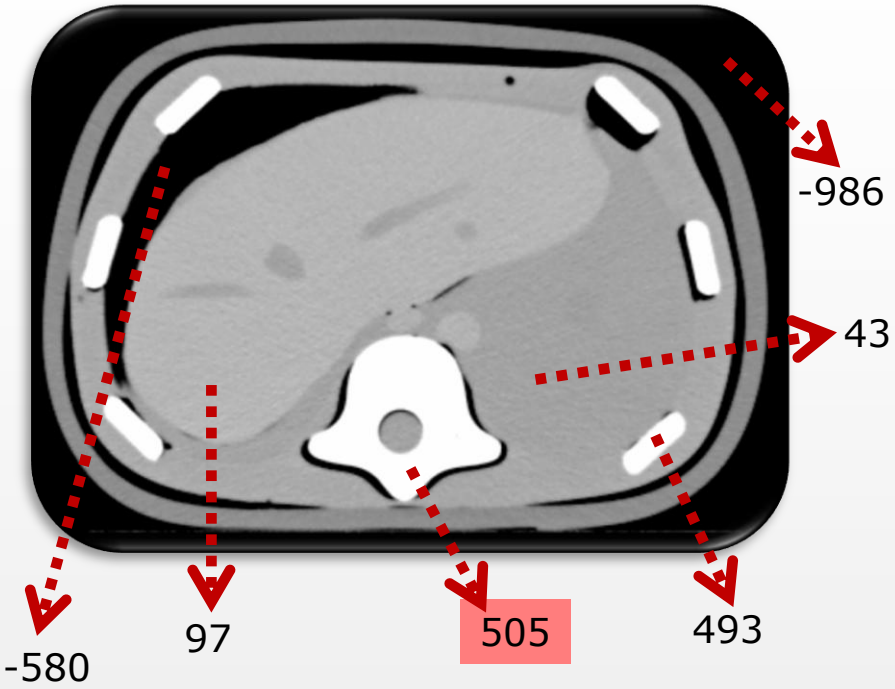


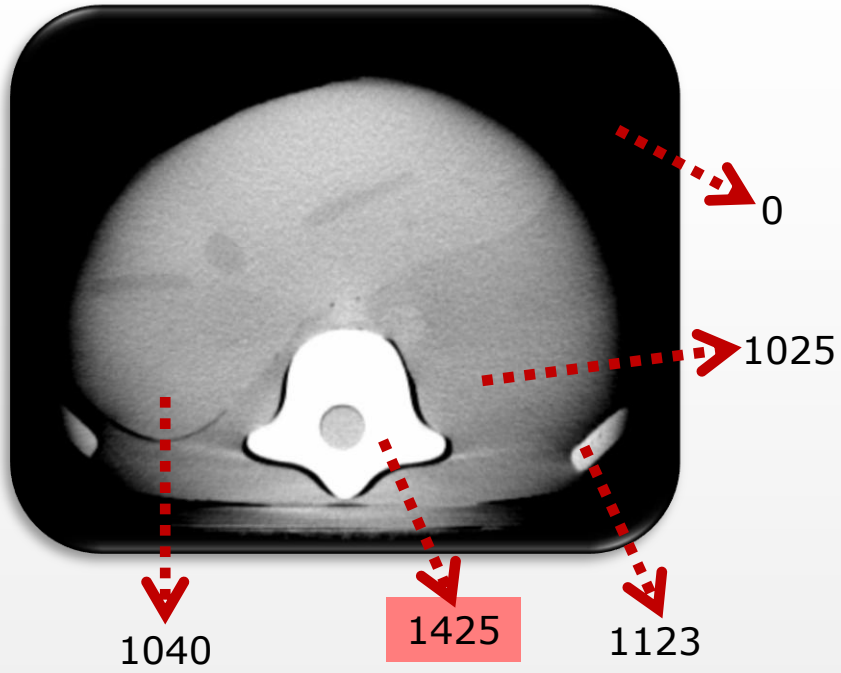
Transverse beam profile (crossline) at 10 mm

- Gamma criterion
  - Lower threshold: 10 % of the maximum dose, 70 % of the maximum dose
  - 3% dose difference and 3 mm distance to agreement (DTA)

	MONTE CARLO	
GAMMA CRITERION (3 mm, 3%)	**Dose > 10%**	**Dose > 70 %**
O-ARM	60.4 %	68.2 %
TrueBeam	93.4 %	97.7 %
BodyTom	100.0 %	100.0 %

Discussion: CT Simulator vs O-ARM





	Hounsfield units
Air	-992
Lung Inhale	-805
Lung Exhale	-506
Adipose	-68
BR 50/50	-37
Water	-4
Muscle	44
Liver	53
Bone 200 mg/cc	223
Bone 800 mg/cc	1076

- O-ARM FOV:
  Ø 20 cm x 15 cm
- Electron density phantom:
  33 cm x 27 cm x 5 cm
- Abdominal phantom:
  26 cm x 19 cm x 12.5 cm

Truncation artifact?

	Hounsfield units
Air	0
Lung Inhale	389
Lung Exhale	530
Adipose	728
BR 50/50	743
Water	752
Muscle	769
Liver	766
Bone 200 mg/cc	864
Bone 800 mg/cc	1125

Conclusions

- Several devices studied in terms of dose distribution estimation rather than image quality

- TrueBeam and BodyTom could be used to estimate the IOERT dose distribution in the real treatment (intraoperative scenario)

- O-ARM:
  - Larger FOV than C-ARMs
  - CT-to-density conversion curve → Not valid

Acknowledgements

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