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Advanced Dosimetry Beyond TG43: Clinical implication for breast brachytherapy

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Disclosures

- I hold a research contract on advanced dose calculation from Elekta/Nucletron

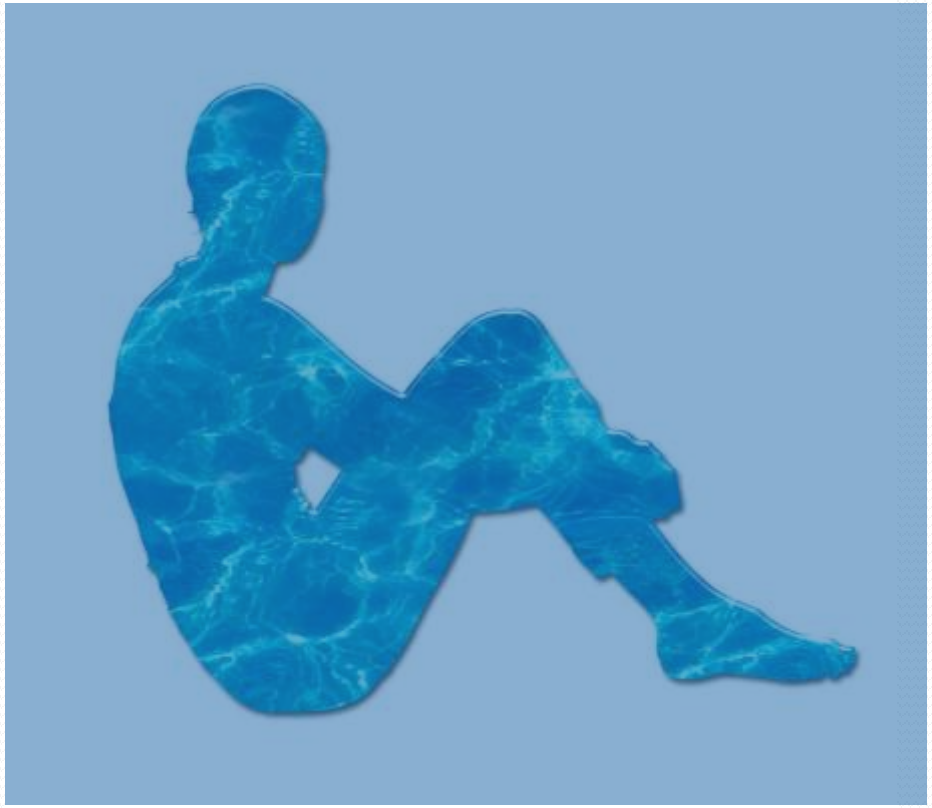
- I am the Chair of the AAPM/ESTRO/ABG Working Group on Model-based Dose Calculation Algorithms.
  - <u>Our WG is working with all brachytherapy TPS vendors</u>.

Contents

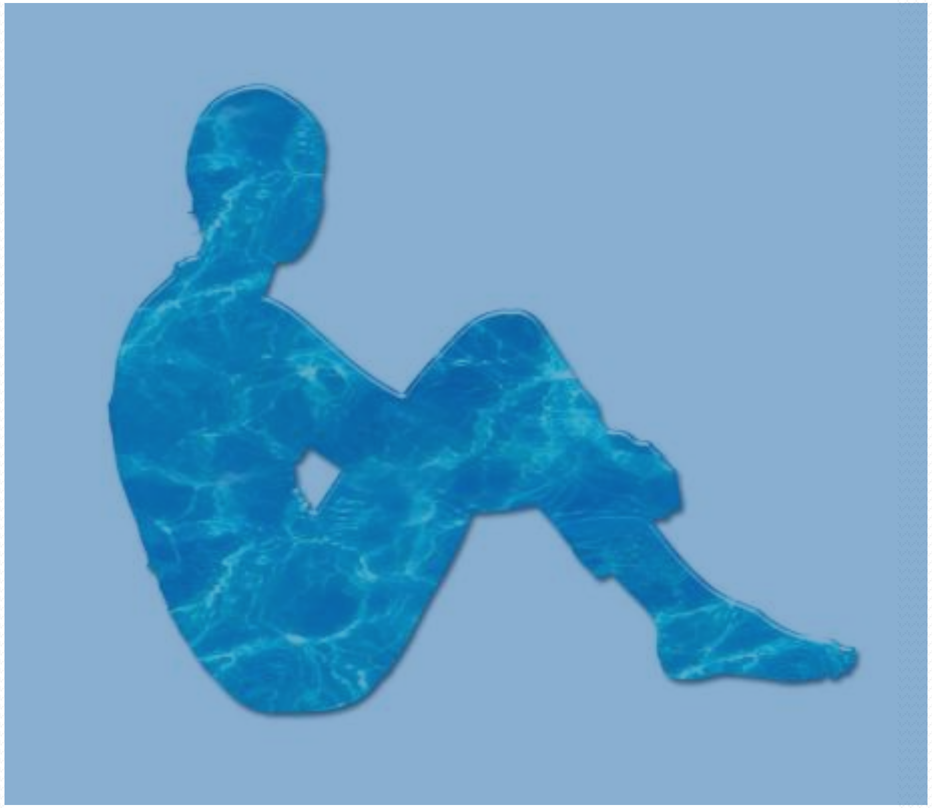
- TG43 and breast brachytherapy
- What to expect going to MBDCA
  - Tissue heterogeneities
  - Scatter condition
  - Contrast agent and air
- A few things to remember moving forward

TG-43 Dose Calculations

TG-43 Dose Calculations



TG-43 Dose Calculations



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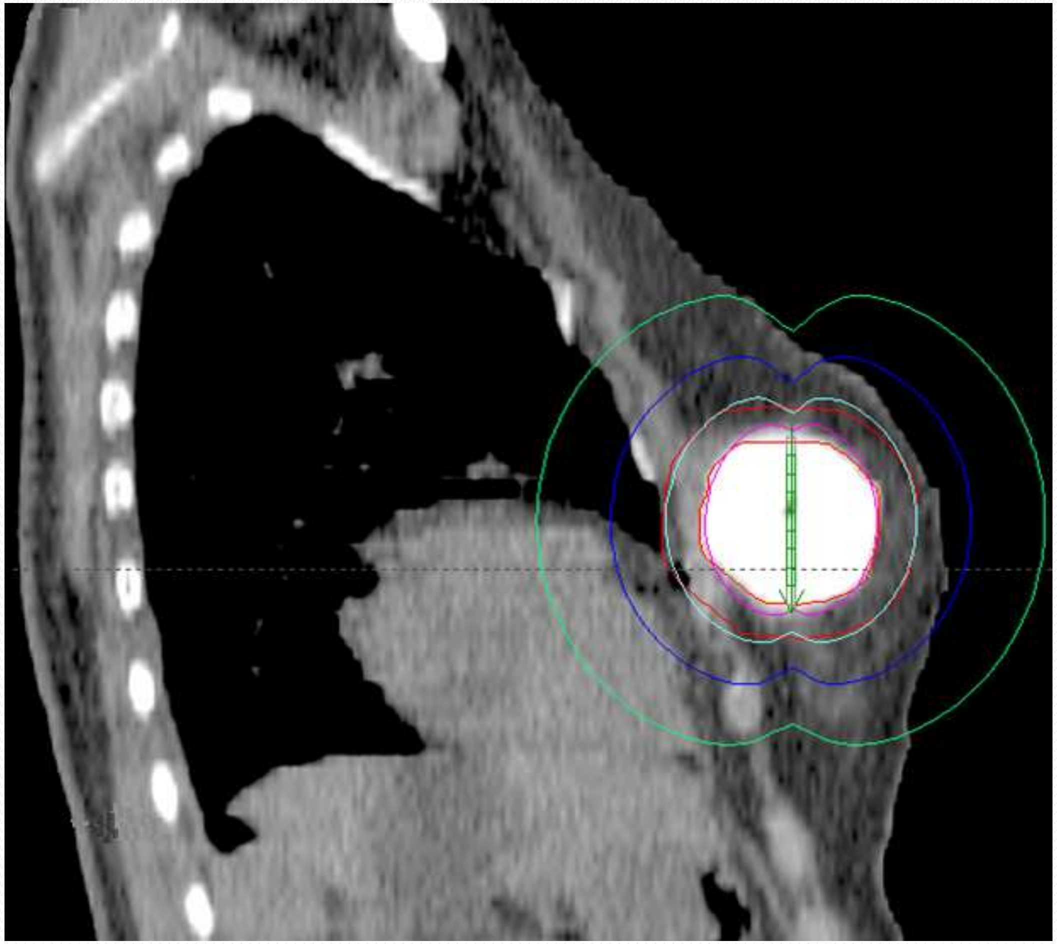
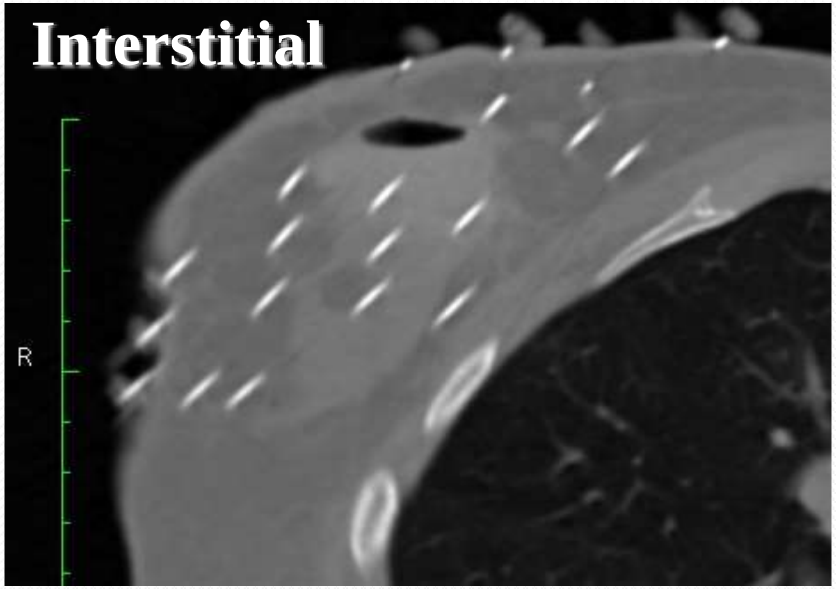
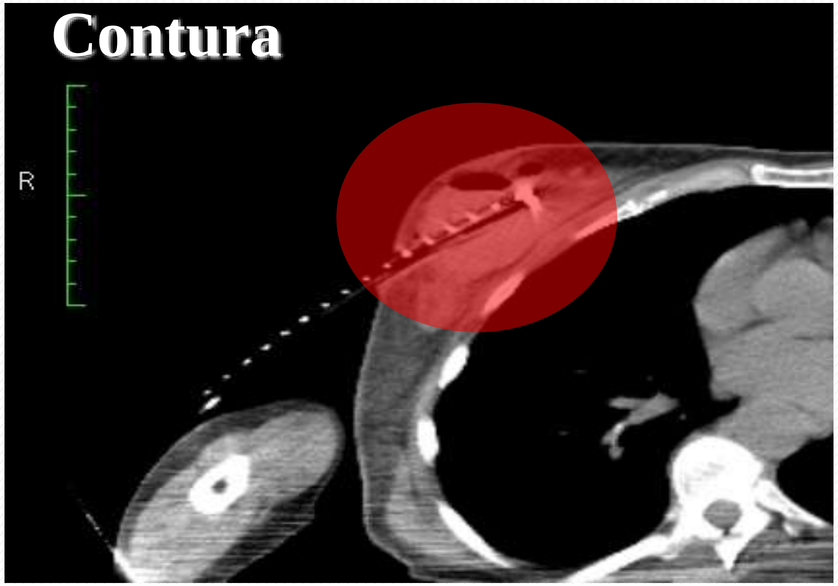
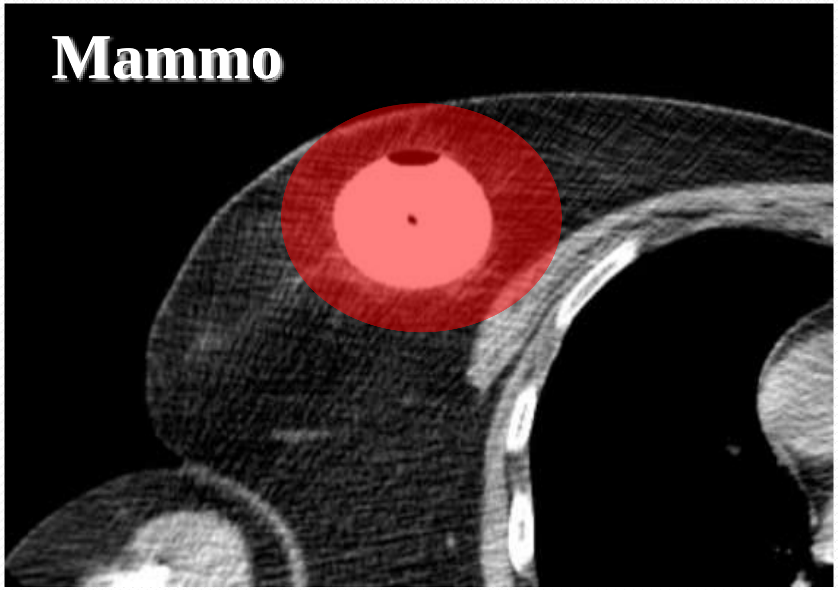


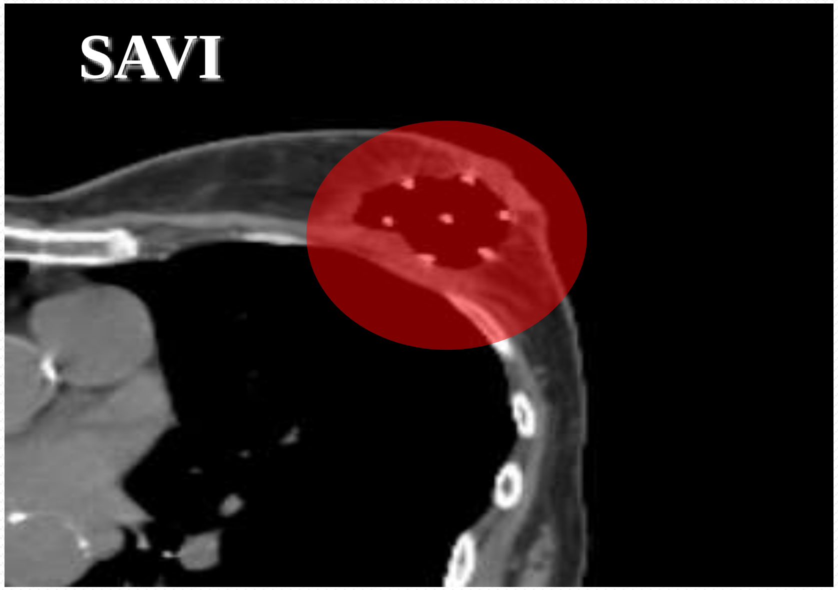
From Rivard

One size does not fit all!









Sensitivity of Anatomic Sites to Dosimetric Limitations of Current Planning Systems

anatomic site	photon energy	absorbed dose	attenuation	shielding	scattering	beta/kerma dose
prostate	high					
	low	XXX	XXX	XXX		
Breast	**High**			X	**XXX**	
	Low	**XXX**	**XXX**	**XXX**		
GYN	high			XXX		
	low	XXX	XXX			
skin	high			XXX	XXX	
	low	XXX		XXX	XXX	
lung	high				XXX	XXX
	low	XXX	XXX		XXX	
penis	high				XXX	
	low	XXX			XXX	
eye	high			XXX	XXX	XXX
	low	XXX	XXX	XXX	XXX	

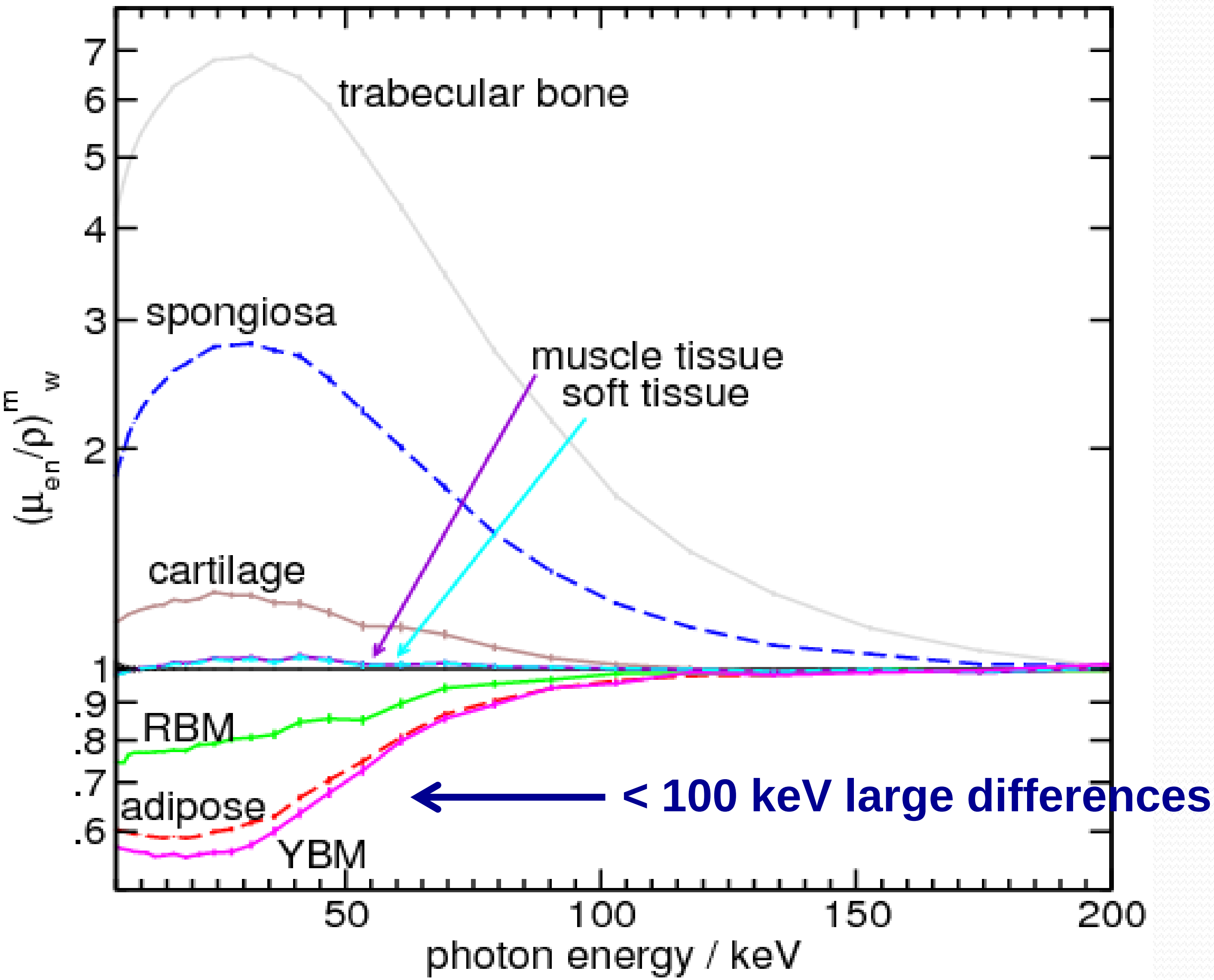
Rivard, Venselaar, Beaulieu, *Med Phys* 36, 2136-2153 (2009)

Rule of tumb

Energy Range	What to look for?
^{192}Ir	interface with air/lung
	Contrast agents
$^{103}Pd/^{125}I$/eBx	Adipose vs glandular tissue
	Air and contrast (balloon)
	Applicators and sources (seeds)

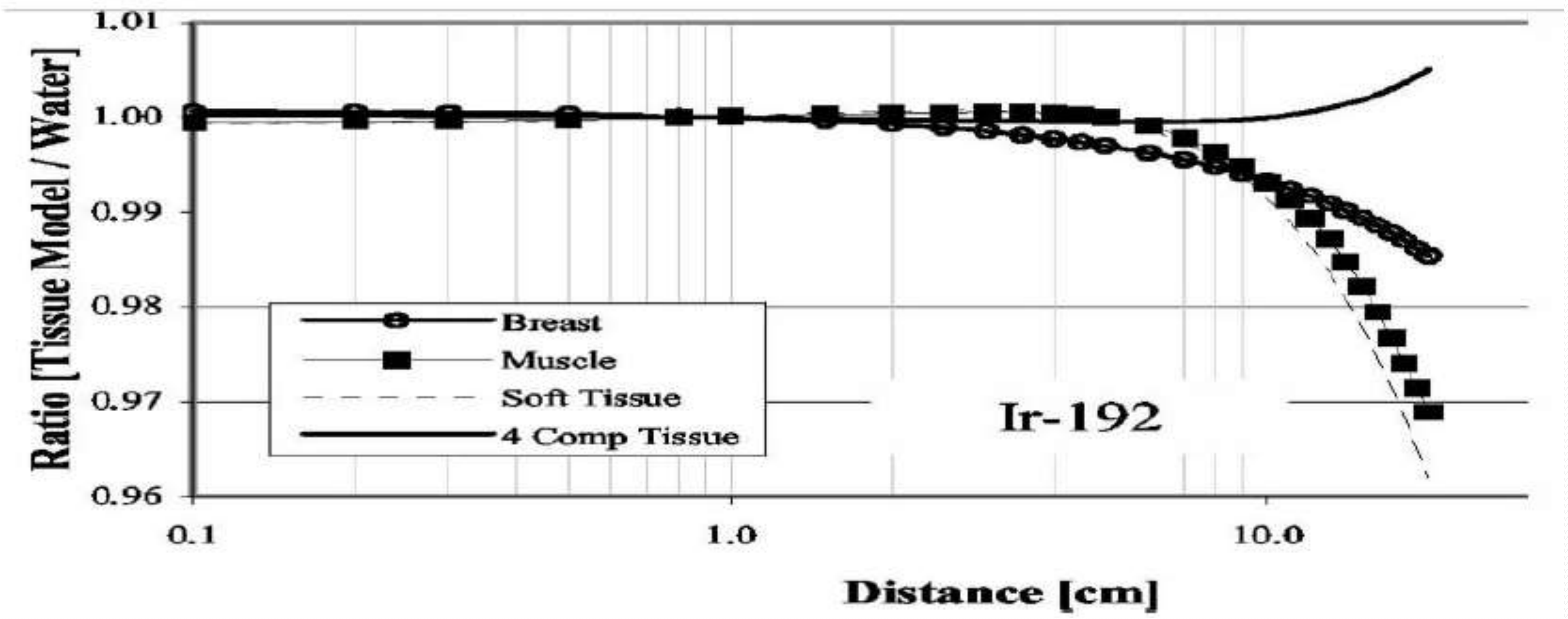
Rivard, Venselaar, Beaulieu, ***Med Phys*** **36, 2136-2153 (2009)**

Water vs Tissues: Photon Energy



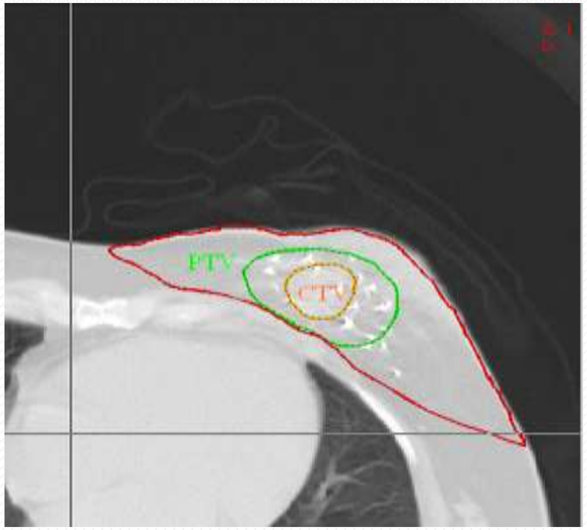
Beaulieu *et al* (TG-186), Med Phys 39, 2012

… Not sensitive at high energy

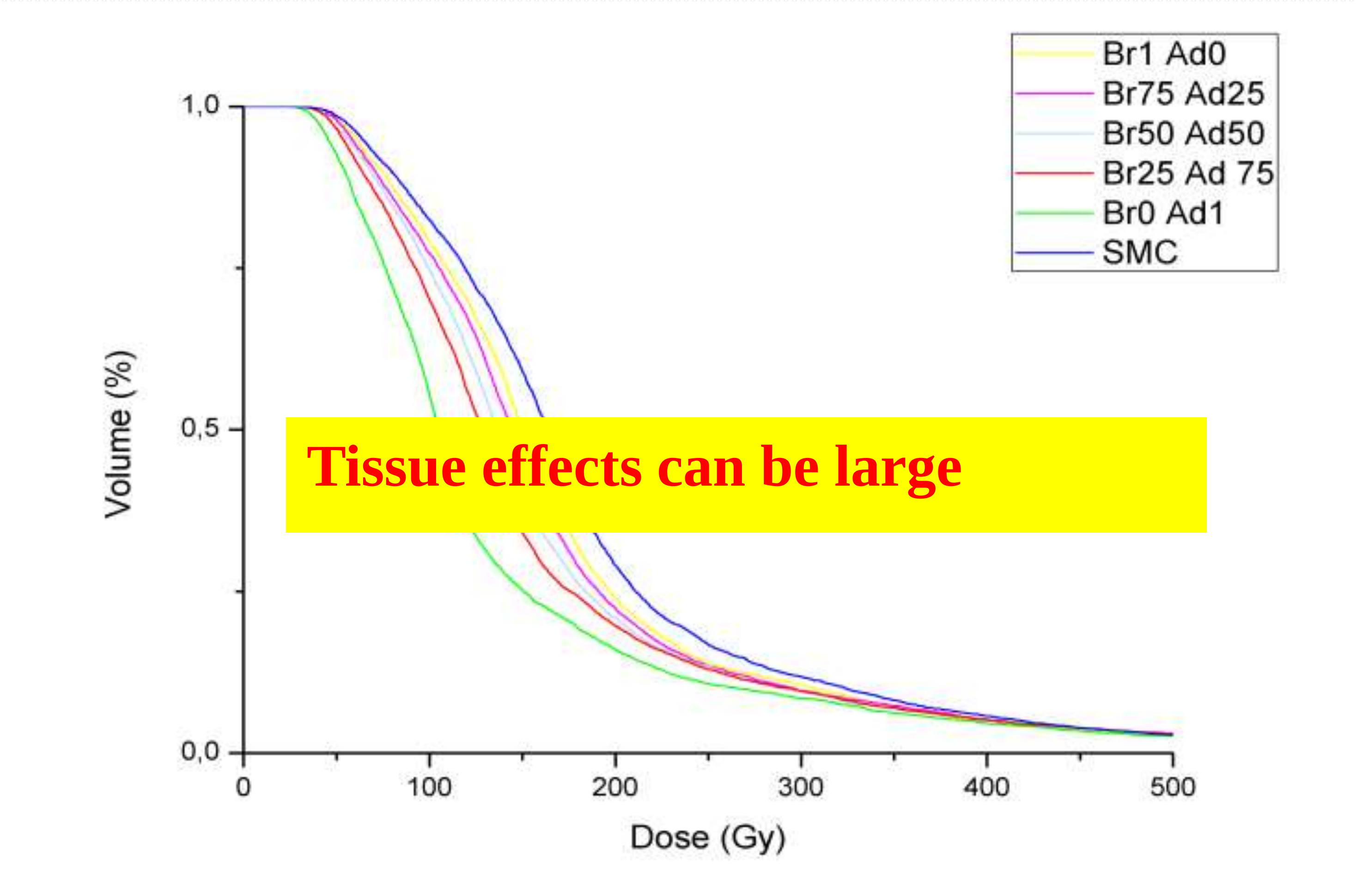


Melhus C S, Rivard M J, « Approaches to calculating AAPM TG-43 brachytherapy dosimetry parameters for Cs-137, Ir-192, Pd-103, and Yb-169 sources », Med. Phys., 33(6), 2006

^{103}Pd Breast Brachytherapy



Keller et al, IJROBP 2005;
Pignol et al, IJROBP 2006

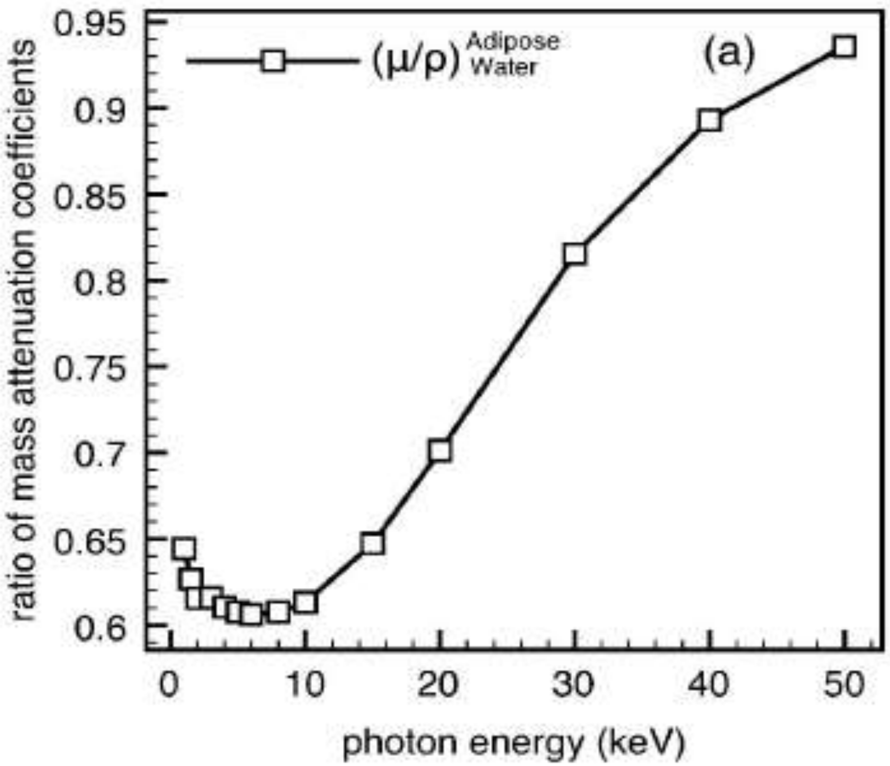


Tissue effects can be large

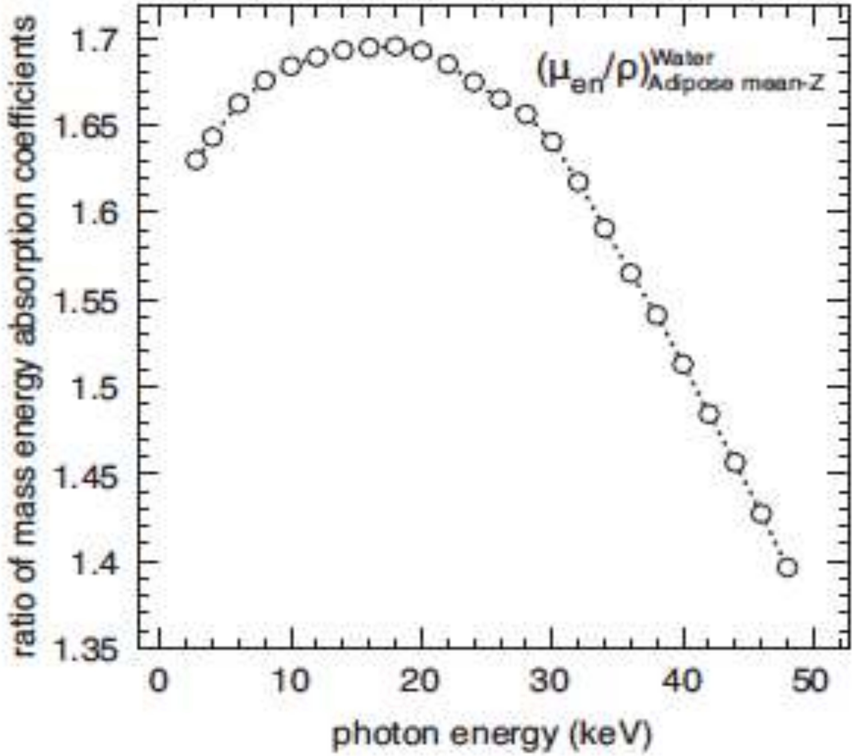
H Afsharpour et al., PMB 2010

Cross sections

Attenuation



$D_{W,M}$ / $D_{M,M}$



G Landry et al., Med Phys 2010 and Med Phys 2011

Dose ratio for a breast case

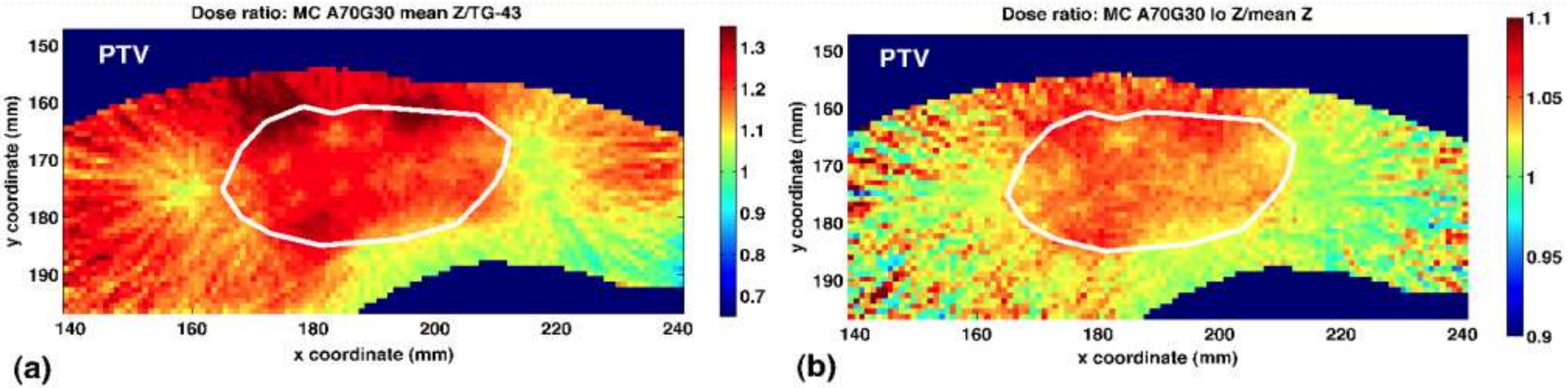


FIG. 7. (a) Ratio of *Breast mean-Z A70/G30* from a brachytherapy breast implant and $D_{\mathrm{TG\text{-}43}}$. (b) Ratio of *Breast lo-Z* over *Breast mean-Z*.

- Left: From water (TG43) to average breast (MC), 30%
- Right: Residual compositional uncertainty, ±10%

G. Landry et al. Med. Phys. 38 (2011)

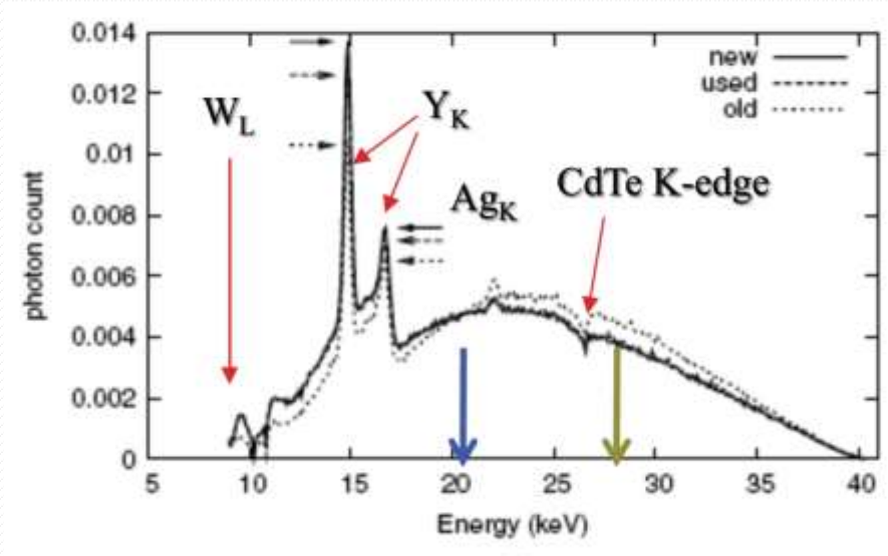
breast electronic brachytherapy study

Shane White, *Evelyn de Jong, Guillaume Landry, Frank Verhaegen, Brigitte Reniers*

Low Energy Brachytherapy

^{125}I and ^{103}Pd seeds:
28 and 21 keV

Axxent electronic BT source: 27 keV

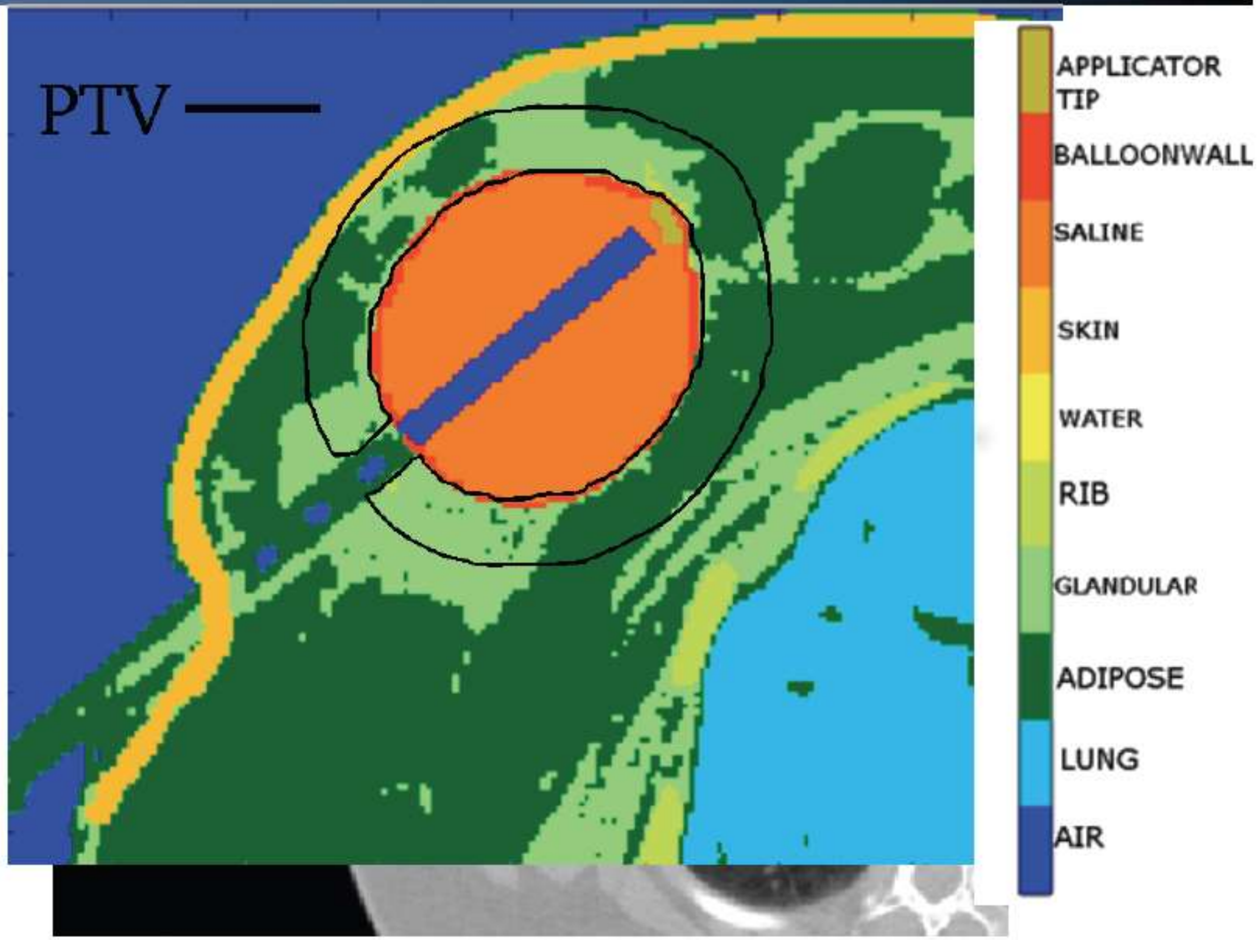


(a)

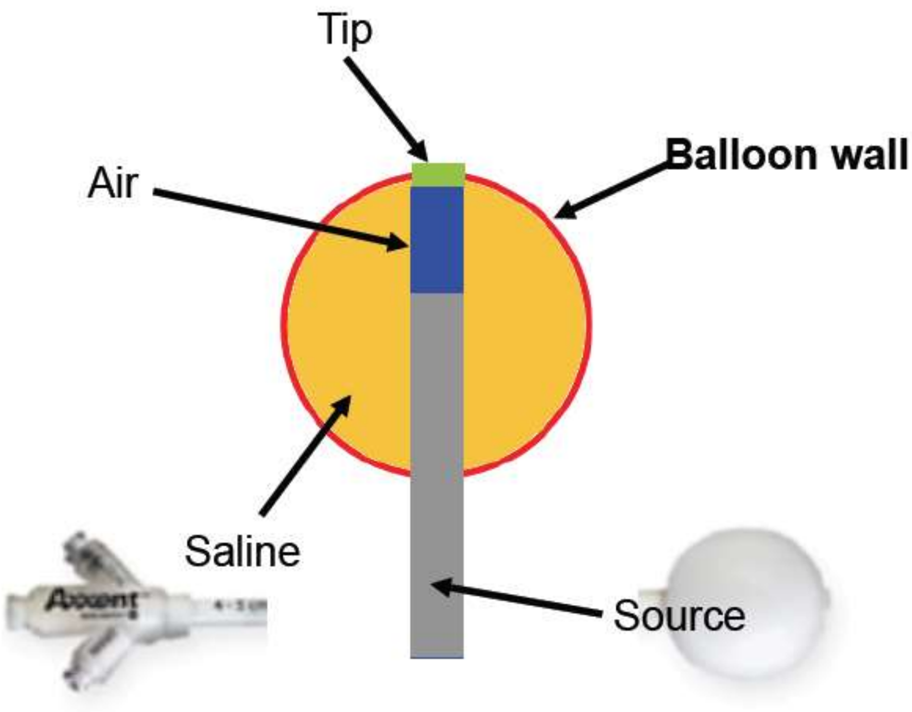
Liu *et al*. PMB 53, (2008)

Xoft Patient TG-186 study

- tissue segmentation using different models presented in TG186
- Manual assignment of skin and contoured geometries
- ICRU 46 compositions



Xoft Patient TG-186 study

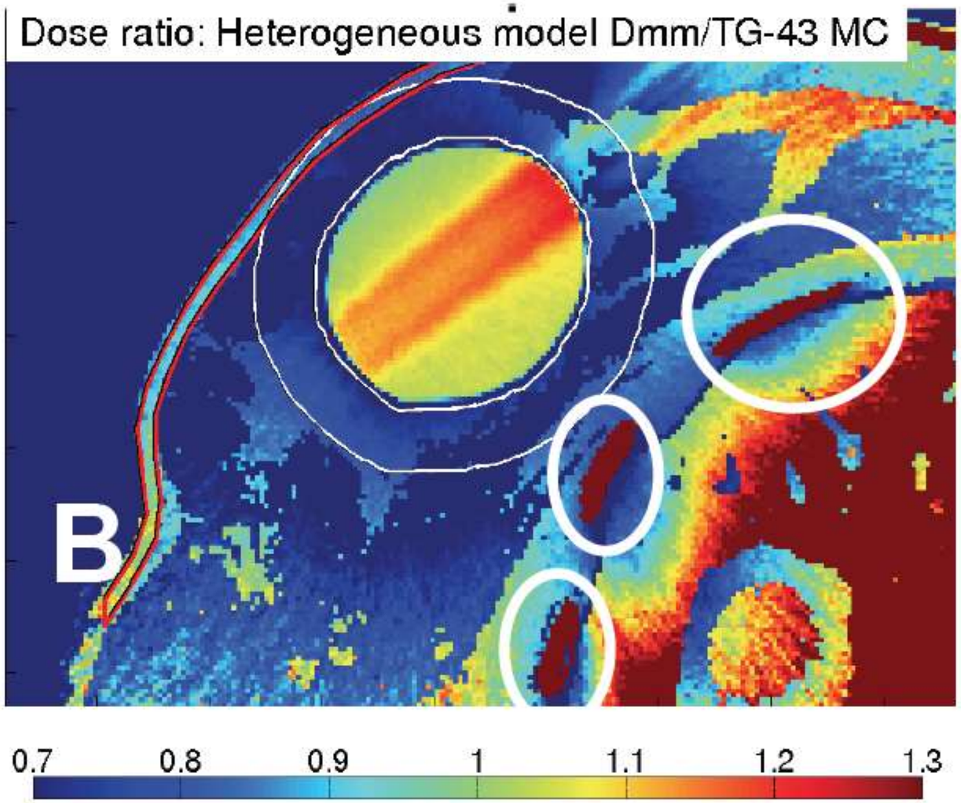


Axxent Balloon Applicator

Balloon wall

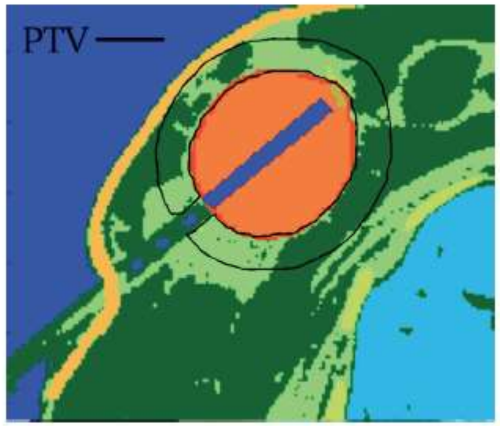
- Contains Barium (Z = 56)
- 0.3 – 0.5mm thick
- Visible on CT
- Attenuates dose by 6% at 1cm from surface
- Dose attenuation larger at distances <1cm
- Cannot be accurately modeled using voxels
- Wall defined as tessellated mesh geometry

TG-186 Heterogeneous Model ($D_{m,m}$)



TG-186< TG-43 TG-186> TG-43

DVH	% differences range
D_{90}	-36% to -33%
V_{100}	- 54% to – 29%
V_{200}	- 97% to - 25%
$D_{0.2cc}$ (Skin)	- 19% to 0%



- Large DVH decreases in $D_{m,m}$ compared to TG-43
- Higher calculated rib dose

Tissue Heterogeneities

Energy dependant

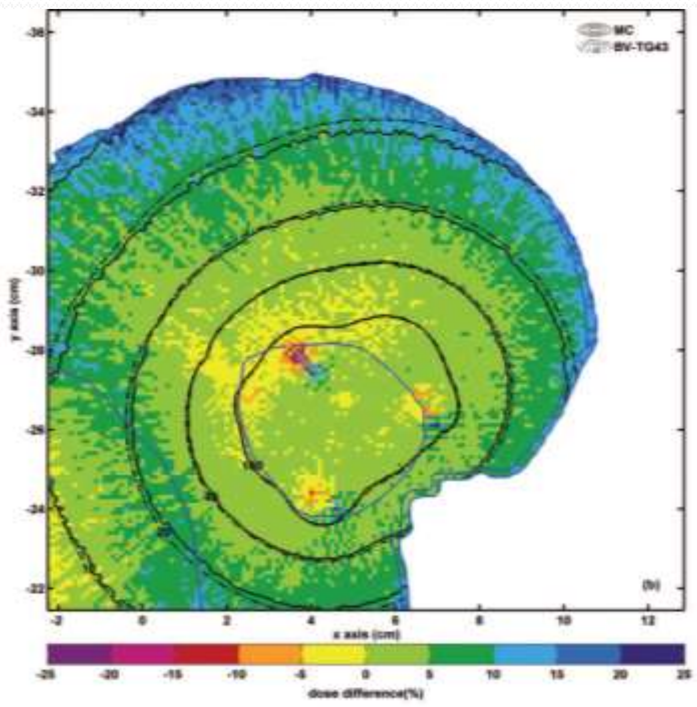
- Less than 1% for ^{192}Ir over useful distances
- 10-40% effect for ^{103}Pd/eBx

- Difference increase with
  - ↓ energy.
  - ↑ distance from *ref* point.

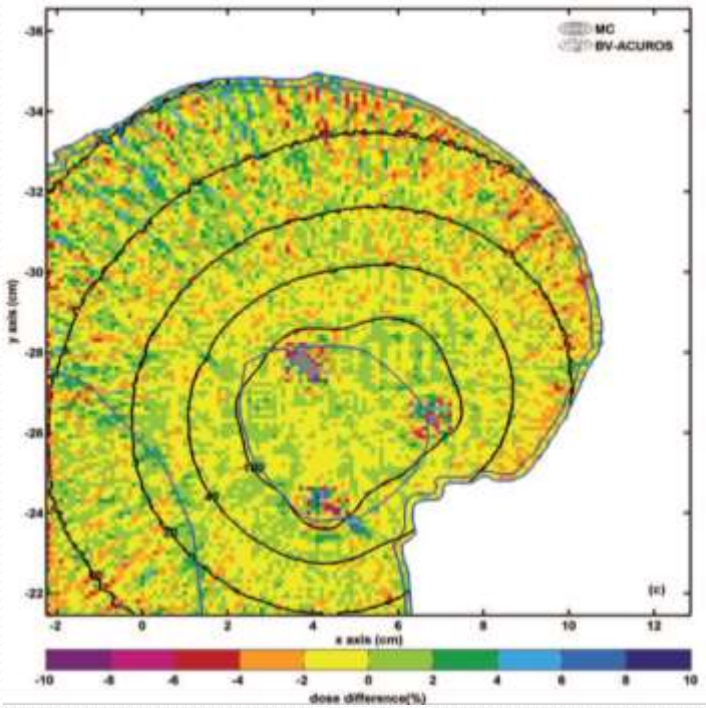
Scatter Condition

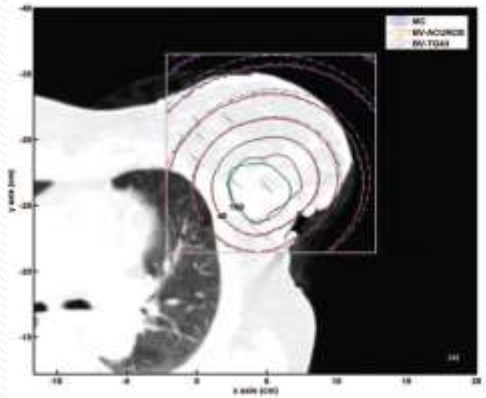
TG43 / MC / Acuros-BV MBDCA

TPS TG43 - MC (%)



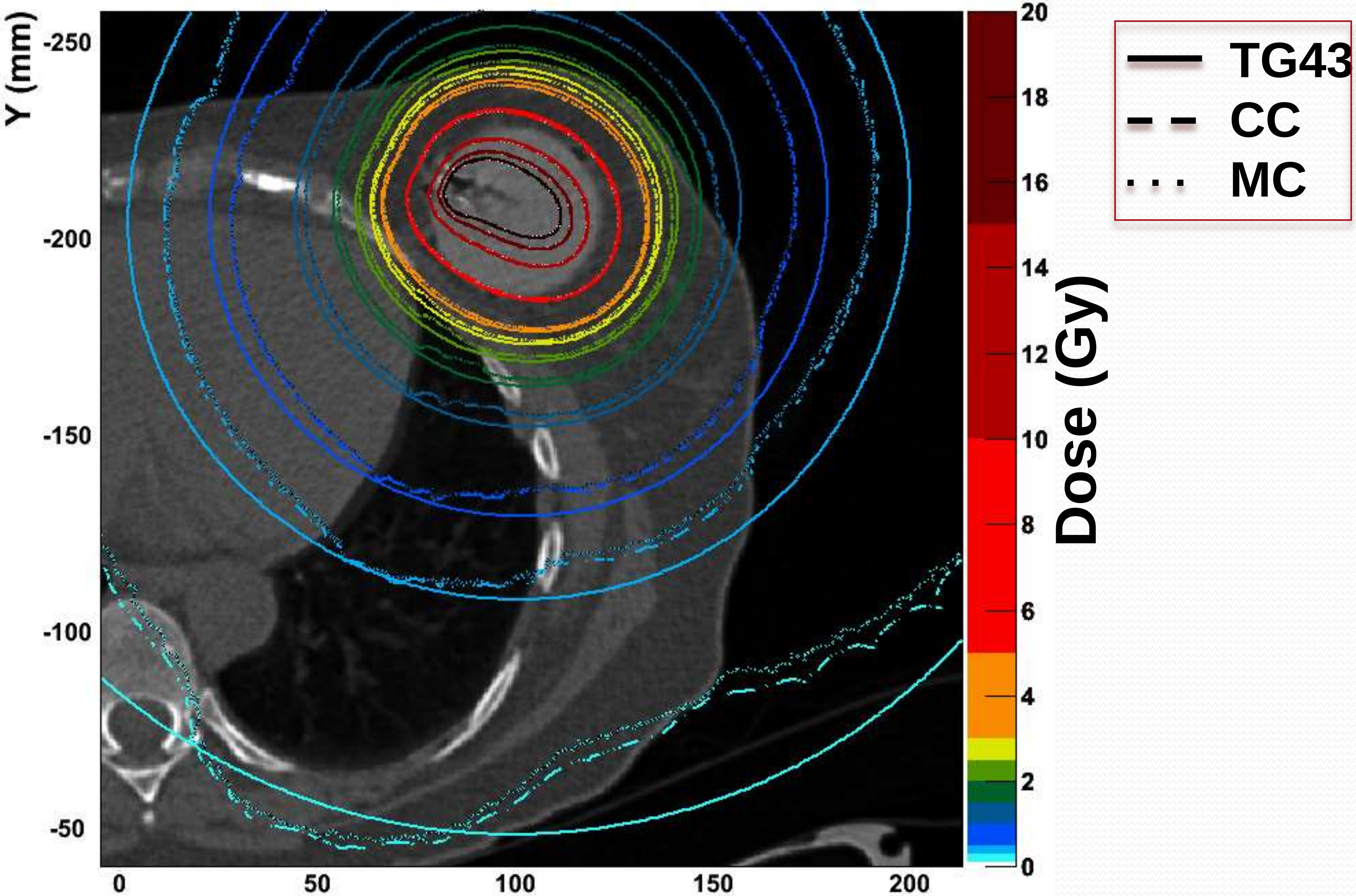
TPS - MC (%)





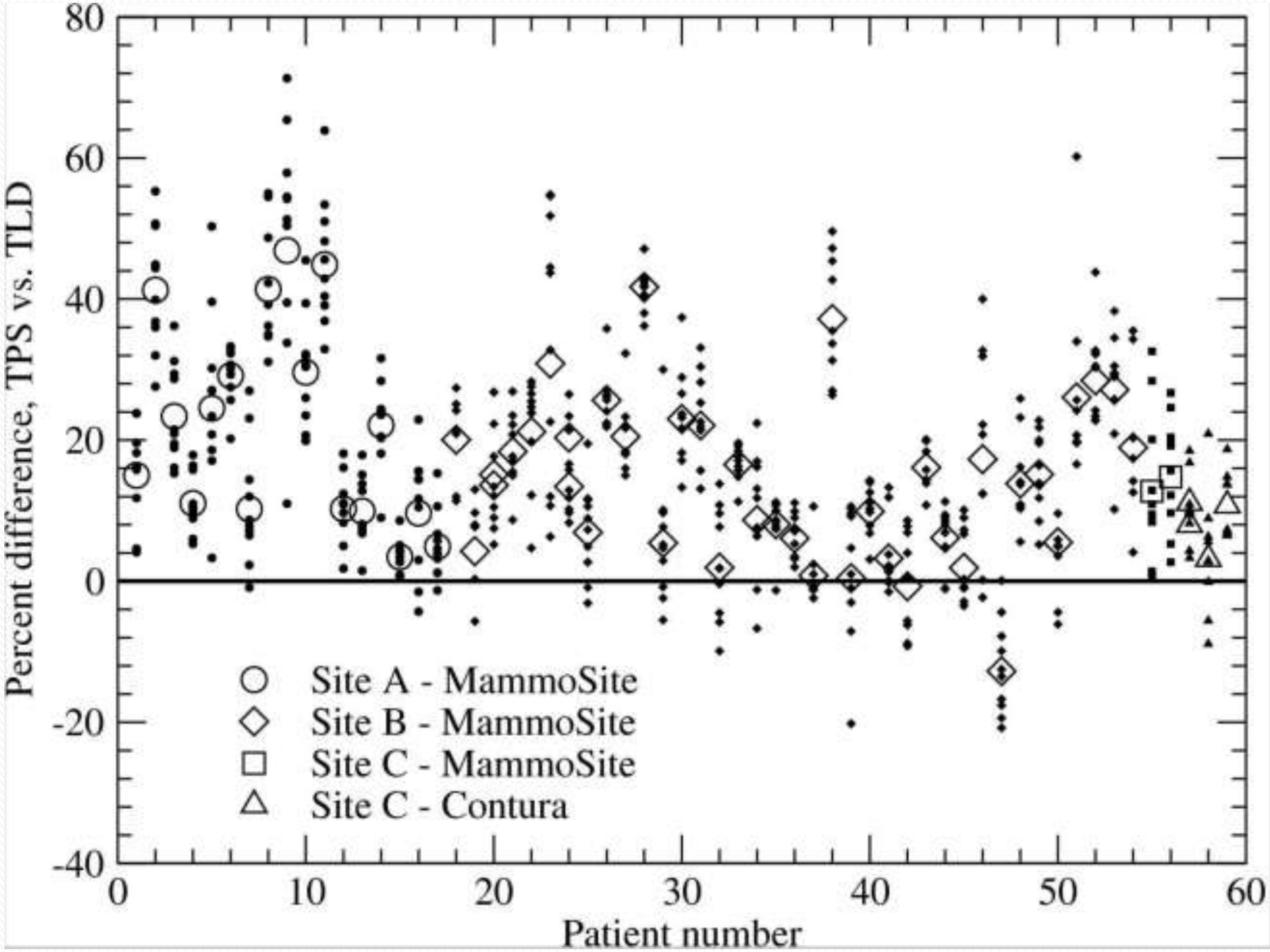
Zourari et al 2012

TG43 / MC / Brachy-CC MBDCA



Plamondon, Carlson-Tedgren and Beaulieu, ABS 2013 meeting

Skin Doses: study on 59 patients



TLD skin dose meas.

- TPS-TLD: -13% to 47%
- Average: 16% overestimation
- MC or GBBS: < 5%

Raffi JA et al, Med. Phys. 37 (2010).

Scatter Condition

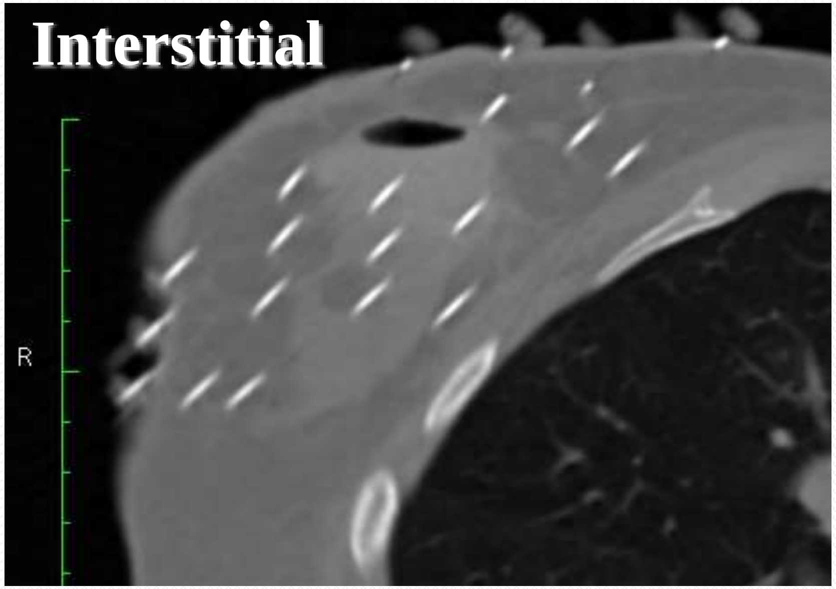
- Finite dimension of the breast for ^{192}Ir
  - No important effect on the highest isodoses
  - Reduces skin doses by 5% or more
    - Pentalis et al., IJROBP 2005; Raffi et al, Med Phys 2010

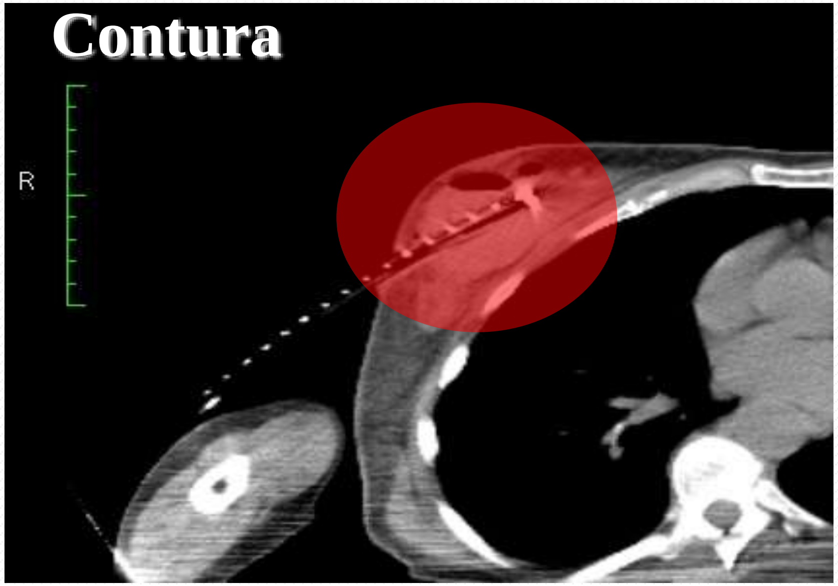
- For lower energy such as ^{169}Yb
  - Skin and lung doses overestimated by 15-30%
    - Lymperopoulou et al., Med Phys 2006

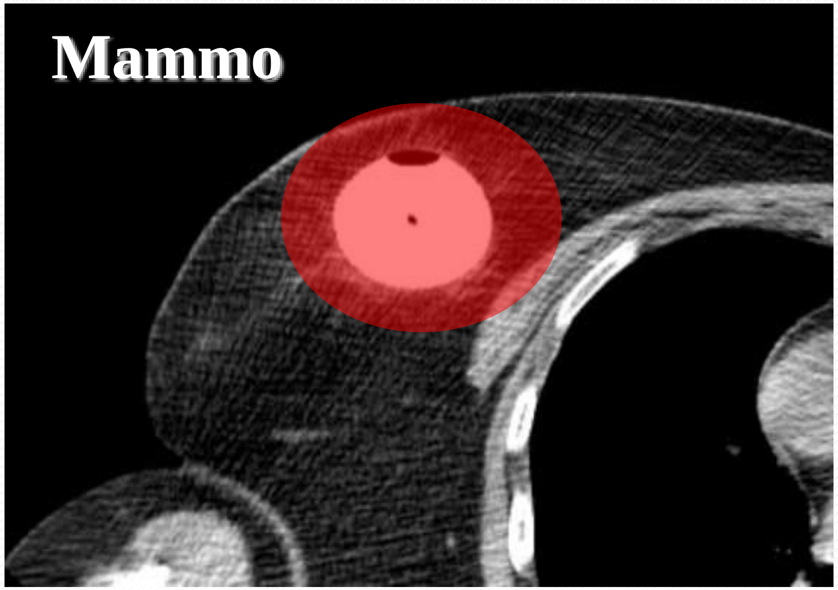
- For even lower energy
  - Not the most important effect anymore…

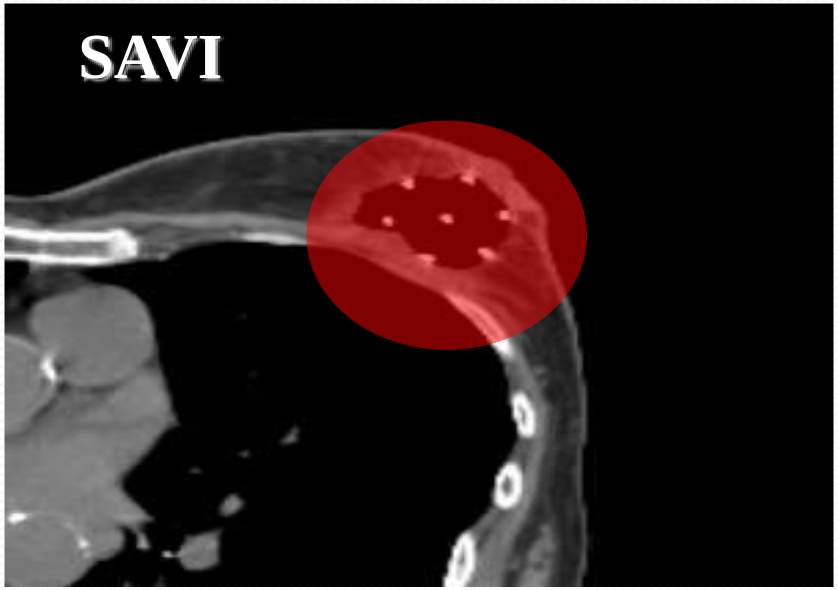
Shielding: Contrast Agent

Contrast and air…









Contrast effects on dosimetry of a partial breast irradiation system

Med Phys 31

Bassel Kassas,[a] Firas Mourtada, John L. Horton, and Richard G. Lane
The University of Texas MD Anderson Cancer Center, Box 94, 1515 Holcombe Boulevard, Houston, Texas 77030

(Received 24 February 2004; revised 6 April 2004; accepted for publication 22 April 2004; published 17 June 2004)

TABLE I. Elemental composition by weight of the simulated contrast solutions. Contrast concentration is given by volume.

% contrast	% carbon	% hydrogen	% iodine	% nitrogen	% oxygen	Density ($g\ cm^{-3}$)
5	1.91	10.64	3.19	0.35	83.90	1.0203
10	3.75	10.11	6.26	0.69	79.18	1.0406
15	5.52	9.60	9.22	1.02	74.64	1.0609
20	5.56	9.11	12.06	1.33	70.27	1.0812
25	8.87	8.64	14.80	1.63	66.07	1.1015

TABLE II. Percentage reduction (Δ%) in dose rate at 1 cm from the balloon due to contrast, relative to water, for the various balloon diameters.

Balloon diameter (cm)	Δ%				
	5% contrast	10% contrast	15% contrast	20% contrast	25% contrast
4	−0.8%	−1.6%	−2.4%	−3.2%	−4.0%
5	−1.0%	−1.6%	−2.7%	−3.8%	−4.9%
6	−1.4%	−2.9%	−4.3%	−5.4%	−5.7%

Dosimetric effects of an air cavity for the SAVI™ partial breast irradiation applicator

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(Received 8 July 2009; revised 3 June 2010; accepted for publication 5 June 2010; published 12 July 2010)

Med Phys 37 (2010)

<u>0 to +9% differences</u>

Depends on:

- Size of the device
- Number of dwell
- Number of strut

Conclusion

- Significant differences between TG-43 and reality
  - Different concerns for high and low energy
- Commercial MBDCA solution only ^{192}Ir
  - Low energy have much large dose *diff.* to solve
- Dose-toxicity relationships and delivered dose levels must be revisited.
  - TG-186 provide strong guidance

Report of the Task Group 186 on model-based dose calculation methods in brachytherapy beyond the TG-43 formalism: Current status and recommendations for clinical implementation

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(Received 7 May 2012; revised 26 July 2012; accepted for publication 2 August 2012; published 25 September 2012)

The charge of Task Group 186 (TG-186) is to provide guidance for early adopters of model-based dose calculation algorithms (MBDCAs) for brachytherapy (BT) dose calculations to ensure practice uniformity. Contrary to external beam radiotherapy, heterogeneity correction algorithms have only recently been made available to the BT community. Yet, BT dose calculation accuracy is highly dependent on scatter conditions and photoelectric effect cross-sections relative to water. In specific situations, differences between the current water-based BT dose calculation formalism (TG-43) and MBDCAs can lead to differences in calculated doses exceeding a factor of 10. MBDCAs raise three major issues that are not addressed by current guidance documents: (1) MBDCA calculated doses are sensitive to the dose specification medium, resulting in energy-dependent differences between dose calculated to water in a homogeneous water geometry (TG-43), dose calculated to the local medium in the heterogeneous medium, and the intermediate scenario of dose calculated to a small volume of water in the heterogeneous medium. (2) MBDCA doses are sensitive to voxel-by-voxel interaction cross sections. Neither conventional single-energy CT nor ICRU/ICRP tissue composition compilations provide useful guidance for the task of assigning interaction cross sections to each voxel. (3) Since each patient-source-applicator combination is unique, having reference data for each possible combination to benchmark MBDCAs is an impractical strategy. Hence, a new commissioning process is required. TG-186 addresses in detail the above issues through the literature review

TABLE OF CONTENTS

Things to remember

- TG-43 is still the recommended STD for:
  - Prescription dose levels
  - Dose planning/optimization
- MBDCA for dose recalculation
  - Building the necessary dose comparison data for each site
  - Follow TG-186 recommendation
    - for tissue assignments
    - For dose reporting

Merci!

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