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Dosimetric Concerns of Post-Mastectomy Tissue Expanders during External Beam Radiation Therapy

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Disclosure

- Nothing to disclose

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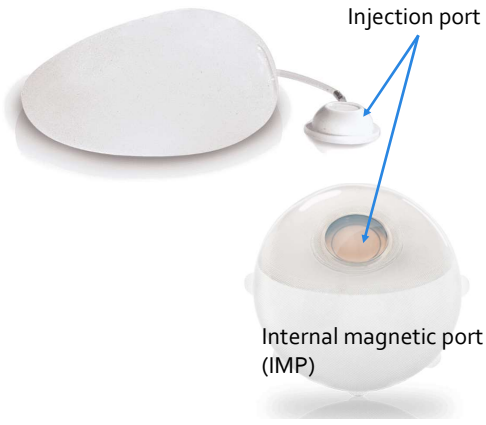
Background

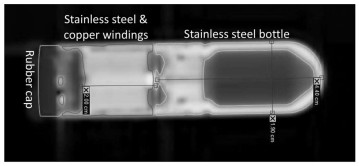
- Breast cancer: Surgery and Radiation Therapy extends life expectacy[1,2]
- Surgical options: Lumpectomy and Mastectomy
- Post-mastectomy:
  - Reconstruction
    - Two-stage technique preferred[2]
  - Post-mastectomy radiation therapy (PMRT)
    - Make skin tighter and tougher
    - Require tissue expander
  - PMRT Timing[3]

1. Fisher B et al. Eight-year results of a randomized clinical trial comparing total mastectomy and lumpectomy with or without irradiation in the treatment of breast cancer. N Engl J Med. 1989 Mar 30;320(13):822-8.
2. Ho AL et al. Postmastectomy radiation therapy after immediate two-stage tissue expander/implant breast reconstruction: a University of British Columbia perspective. Plast Reconstr Surg. 2014 Jul;134(1):1e-10e.
3. Oliver JD et al. Postmastectomy Radiation Therapy (PMRT) before and after 2-Stage Expander-Implant Breast Reconstruction: A Systematic Review. Medicina (Kaunas). 2019 May 29;55(6):226.

Tissue Expanders



- Saline-based tissue expander
- Weekly injection
- 6- 8 weeks

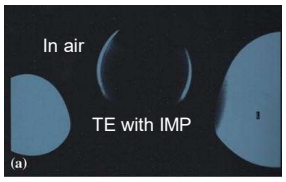


Dziemianowicz E et al. JACMP. 2019

- Air tissue expander
- Self-administered
- Up to 3 times a day
- 4- 6 weeks

MRI Safety

- Concerns
  - Heating
  - Projectile effect
  - Artifacts
- Saline with magnetic injection port
  - MR unsafe
  - Port dislodgement[1]
- Air Tissue Expander
  - MR unsafe
  - Stainless steel
  - CO_2 canister
  - Not recommended



Nava, M.B et al, Aesth Plast Surg 2012.

Patete CL et al, Aesthet Surg J Open Forum. 2020

1. Zegzula HD, Lee WP. Infusion port dislodgement of bilateral breast tissue expanders after MRI. Ann Plast Surg. 2001 Jan;46(1):46-8.

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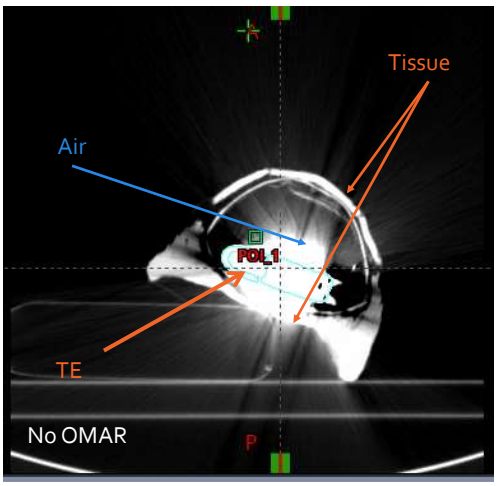
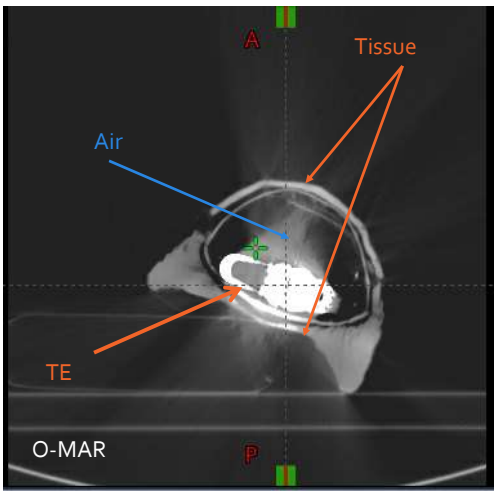
CT Challenges





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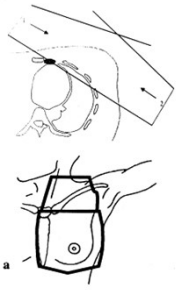
External Beam Radiation Therapy Consideration

- Radiation dose homogeneity is important
  - Correlated to the outcome
  - Coverage (Chest wall to the skin)
  - OAR (Contralateral breast, heart, lung)

- Techniques
  - Parallel oppose
  - VMAT / IMRT

- Treatment
  - Photon
  - Proton
  - Brachytherapy



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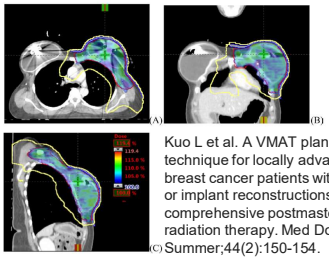

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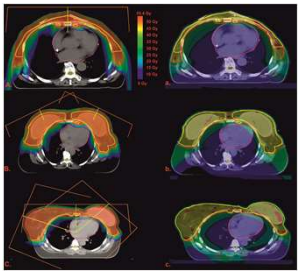

Melissa A. L. et al.; Techniques for Treating Bilateral Breast Cancer Patients Using Pencil Beam Scanning Technology. *Int J Part Ther* 1 September 2019; 6 (2): 1–11.

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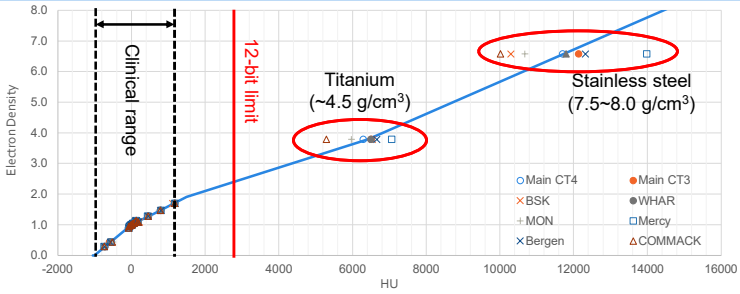
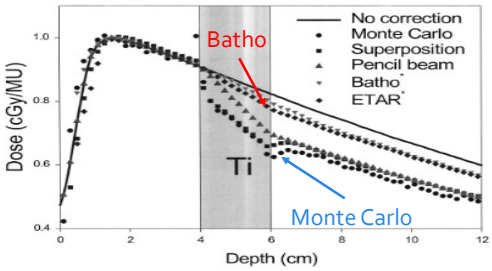
Expander Dosimetric Complications

- CT curve
  - 12-bit limit
  - High Z material calibration
  - Inaccurate HU
  - Delineation challenge

- Coverage
  - Affect dose homogeneity
  - Increase uncertainty

- Dose calculation algorithm accuracy*
  - Z, energy, and field size dependent
  - E > 10MV
    - neutron dose may not be included
  - Algorithm





Report of the AAPM Radiation Therapy Committee Task Group 63. Med Phys. 2003 Jun;30(6):1162-82.

*TG-63 and TG-65

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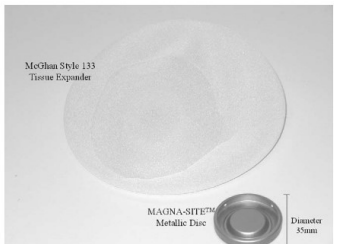
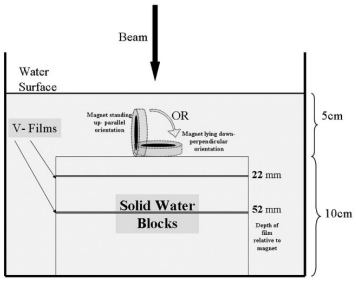
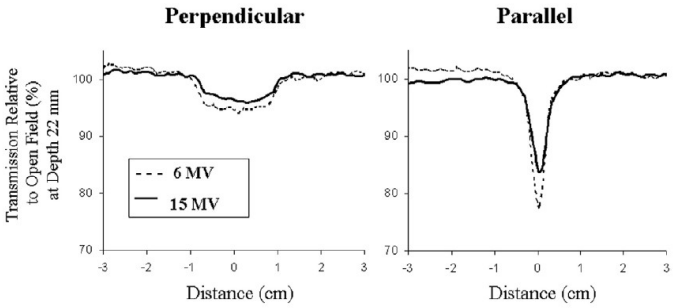
Dosimetry - IMP







Damast S et al. Int J Radiat Oncol Biol Phys. 2006 Sep 1;66(1):305-10.

1. Significant transmission reduction behind the magnet (shadow)
2. Without correction, dose error >20% (6x) and > 10% (15x)
3. Parallel to the beam is significant worse
4. 15x less attenuation than 6x
5. Average skin dose error: -14% to +1%

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Dosimetry - IMP

- Clinical beam dosimetric error
  - Less significant with multiple beams
- Algorithm
  - AAA and CCC tend to overestimate
- Chest wall
  - IMP typically > 1 cm away
  - Not too critical
- Skin
  - Potential underdose
- Saline Cavity
  - Significant dose inhomogeneity
  - Not critical

Dose error (%)	AAA[1]	CCC[2]
Skin	~7% (0°)	5-10%
Chest Wall	Not sig	< 1.0%

Amount of Bolus Guideline for Breast/Chestwall Treatment

Planner is only responsible for checking basic physics guideline- beyond that is MD discretion

	Clinical Situation	Tangent fields, 6MVX	Tangent fields, 15MVX (Only for Tissue Expander and/or for Center Breast ≥ 25 cm** at posterior border)	IMRT/VMAT, 6MVX
Basic Physics Bolus	Intact Breast	--	3 mm daily	3 mm daily**
	Tissue expander	-- (Do not use 6MVX Tangents)	1 cm daily	3 mm daily
	Mastectomy (with or without prosthesis)	3 mm daily	1 cm daily	3 mm daily

1. Trombetta DM, Cardoso SC, Facure A, da Silva AX, da Rosa LA. Influence of the presence of tissue expanders on energy deposition for post-mastectomy radiotherapy. PLoS One. 2013;8(2):e55430
2. Yoon J, Xie Y, Heins D, Zhang R. Modeling of the metallic port in breast tissue expanders for photon radiotherapy. J Appl Clin Med Phys. 2018 May;19(3):205-214.

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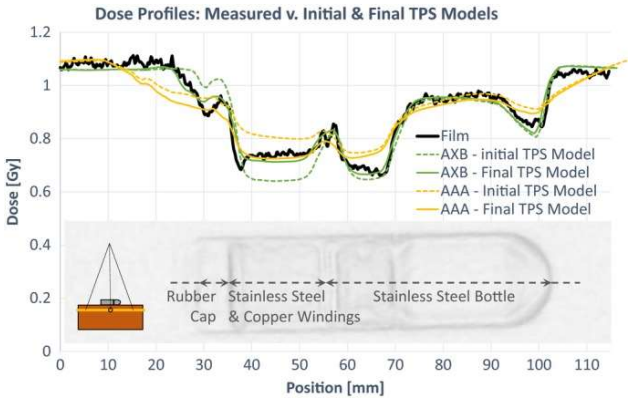
Air Tissue Expander

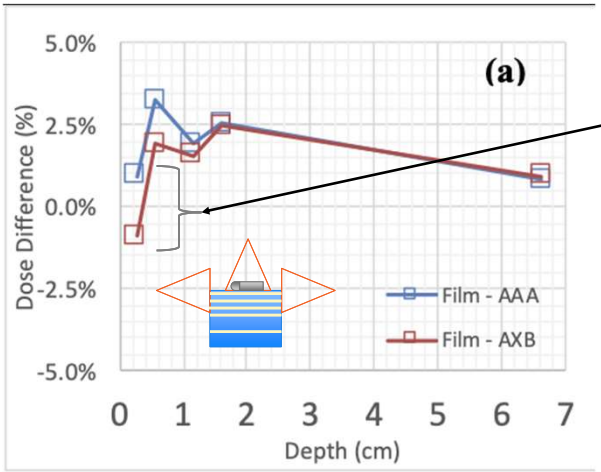
- Complex high Z structure

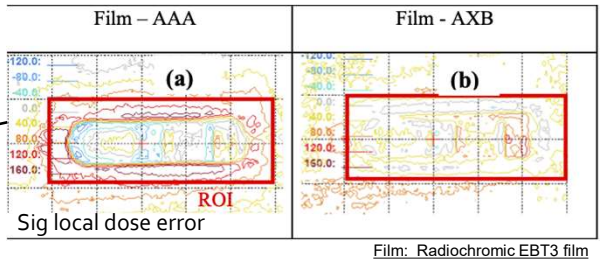


Mean dose	Patient No. 1			Patient No. 2			Patient No. 3			Patient No. 4		
	AAA (Gy)	AXB (Gy)	Δ (%)	AAA (Gy)	AXB (Gy)	Δ (%)	AAA (Gy)	AXB (Gy)	Δ (%)	AAA (Gy)	AXB (Gy)	Δ (%)
CO_2 Reservoir	45.2	42.9	5.4%	49.2	46.8	5.0%	51.2	48.0	6.9%	48.3	44.8	7.7%
Expander balloon	54.3	49.2	10.4%	53.2	47.3	12.5%	53.2	47.3	12.6%	53.8	50.7	6.2%
PTV_EVAL	51.1	51.4	−0.6%	50.6	51.3	−1.3%	49.1	49.2	−0.3%	52.1	52.8	−1.3%
Chest wall AF	49.6	52.2	−5.0%	48.7	49.2	−1.1%	49.9	50.4	−1.1%	52.1	54.4	−4.2%
Dose shadow AF	49.8	50.1	−0.5%	48.3	49.3	−2.0%	53.0	54.2	−2.2%	47.2	49.6	−4.8%

Dziemianowicz E et al. JACMP, 2019

Dosimetry (with 16 bits and O-MAR)





Film: Radiochromic EBT3 film

OSLD Analysis		6x (VMAT)		15x (Tangent)	
		AAA	AXB	AAA	AXB
Chest wall	min	-2.2%	-2.9%	-5.8%	-5.9%
	max	13.8%	11.0%	9.9%	4.9%
	<DD>	4.6%	1.6%	3.9%	0.4%

Lim, S.B. et al. JACMP 2000

Some Final Thoughts

- Avoid high Z if possible
- CT curve
  - 16 bits if available
  - Appropriate density correction
  - Metal Artifact Reduction (MAR)
    - iMAR (Siemens)
    - O-MAR (Philips)
    - SmartMAR (GE)
    - SEMAR (Toshiba)
- Algorithm
  - With inhomogeneity correction[1]
    - AAA, AXB, CCC
  - Classic algorithms should be avoided[2]
  - AAA and CCC tend to be inferior[3,4] with high Z or low density than AXB or MC
- Evaluate TE

1. Chen et al. Impact of internal metallic ports in temporary tissue expanders on postmastectomy radiation dose distribution. Int J Radiat Oncol Biol Phys. 2013 Mar 1;85(3):630-5.
2. Roberts R. Phys Med Biol. 2001 Sep;46(9):N227-34.
3. Ojala J et al. The accuracy of Acuros XB algorithm for radiation beams traversing a metallic hip implant - comparison with measurements and Monte Carlo calculations. J Appl Clin Med Phys. 2014 Sep 8;15(5):4912.
4. Han T et al. Dosimetric comparison of Acuros XB deterministic radiation transport method with Monte Carlo and model-based convolution methods in heterogeneous media. Med Phys. 2011 May;38(5):2651-64.

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Thank You