3D Dosimetry in the Clinic and Research

3D DOSIMETRY IN END-TO-END DOSIMETRY QA

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Disclosures

My institution holds Master Research Agreements with Varian, Elekta, and Philips

I will be discussing devices that are not currently available for sale, and that do not have FDA clearance.

Learning objectives

1: 3D Dosimetry in the Clinic: Background and Motivation

2: 3D Dosimetry in the Clinic: Motion interplay effects in dynamic radiotherapy

3: 3D Dosimetry in the Clinic and Research: Validating Special Techniques

4: **3D Dosimetry in end-to-end dosimetry QA**

- Evidence of need for E2E dosimetry
- Benefits of 3D dosimetry for E2E testing
- Specific examples of 3D dosimetry and E2E tests

Errors in Radiation Therapy

1. Errors in medicine occur too often
    - IOM study: ~98,000 deaths/year
    - New York Times series:
        - St. Vincent's Hospital: IMRT error
        - Moffitt Cancer Center: Calibration error
2. QA is essential
    - Equipment is more complex
    - Techniques are more complex
    - Risk to patient from error is greater
    - Most institutions report insufficient staff

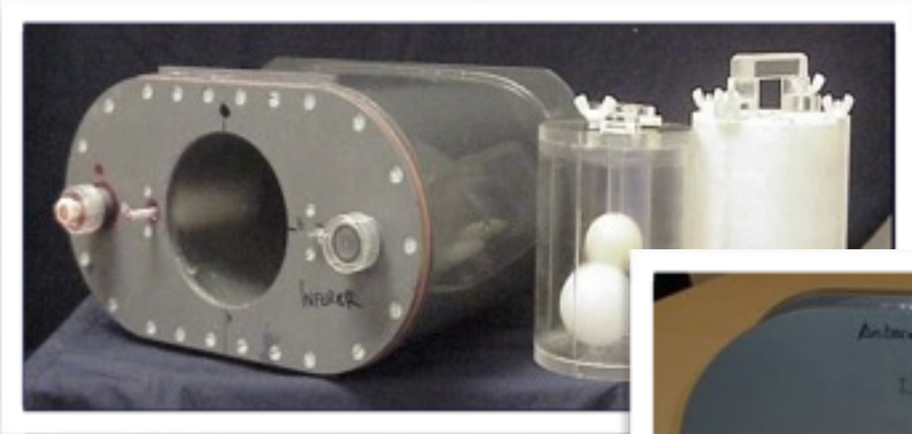
What causes things to go wrong?*

Selected Causes/Contributing factors	
Therapist error	84%
Failure to follow policies/procedures	63%
Incorrect body part	46%
Physics/Dosimetry	27%
Wrong patient	19%
Inadequate policies/procedures	16%
RO error	12%

***New York State**

Courtesy Peter Dunscombe: "Safety in Radiation Therapy: A call to action"

IROC Phantoms



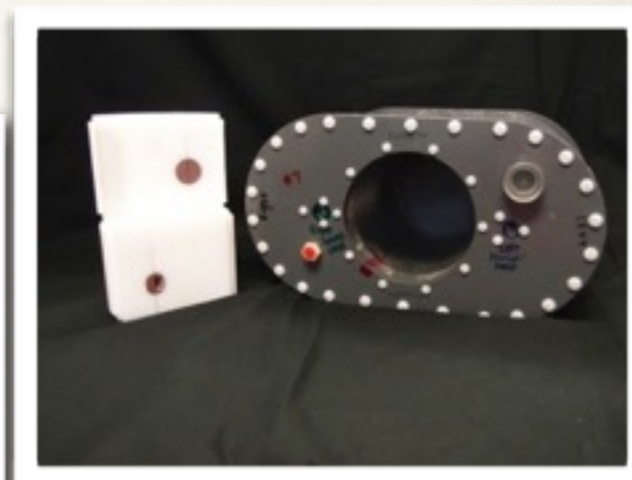
Pelvis (10)

Thorax (13)

Spine (4)

H&N (31)

SRS Head (4)



Liver (2)

IROC Phantom Results

Comparison between institution's plan and delivered dose.

Phantom	H&N	Liver	Lung	Prostate	Spine
Irradiations	1351	9	484	411	168
Pass	1118 (83%)	6 (67%)	394 (81%)	352 (86%)	113 (67%)
Fail	233	3	90	59	55
Criteria	7%/4mm	7%/4mm	5%/5mm	7%/4mm	5%/3mm

RPC MD Anderson Radiological Physics Center

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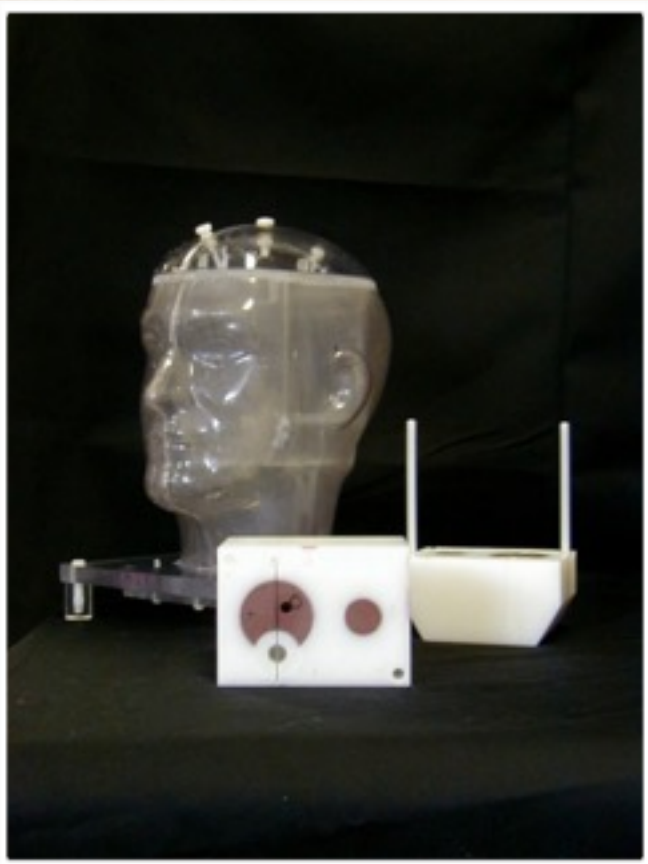
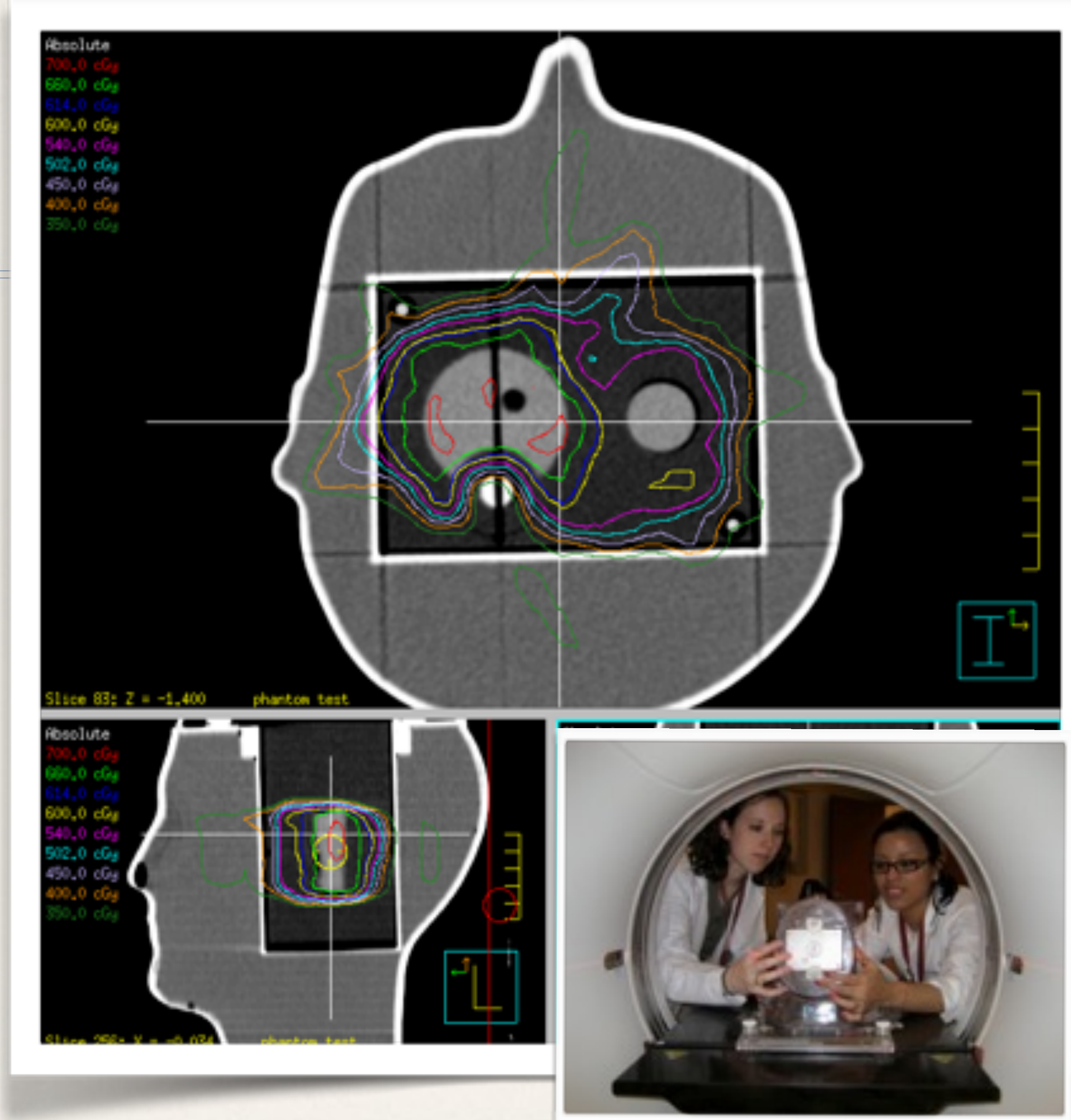
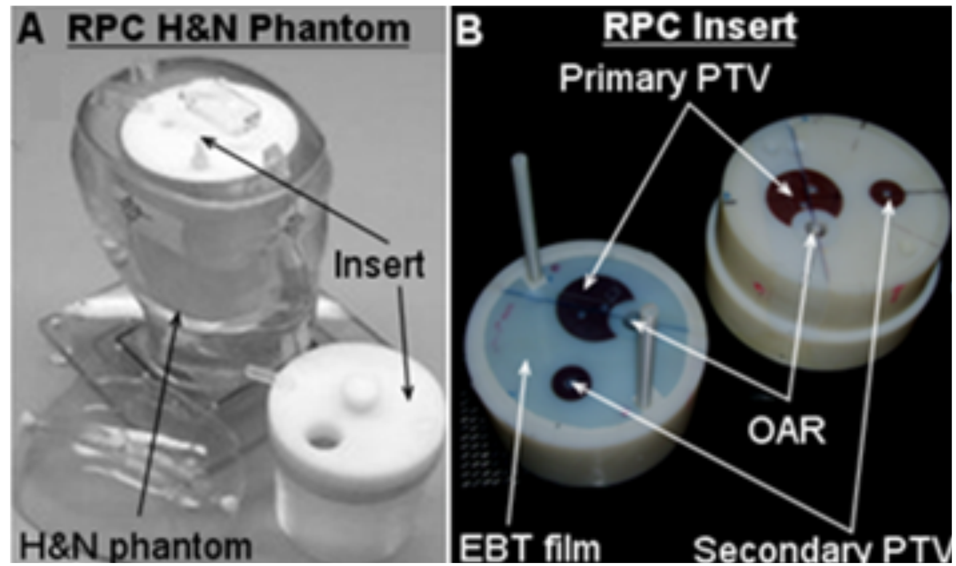
H&N Phantom

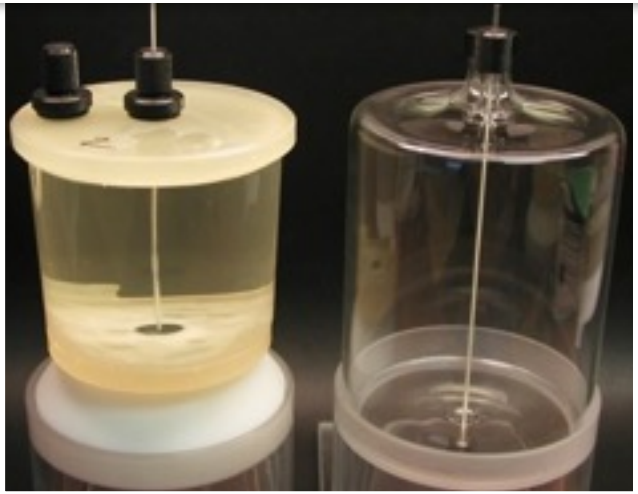



Absolute
700.0 cGy
660.0 cGy
614.0 cGy
600.0 cGy
540.0 cGy
502.0 cGy
450.0 cGy
400.0 cGy
350.0 cGy
Slice 83: Z = -1.400
phantom test

Volumetric Dosimeters

- Fricke Gel
- Polymer Gel
- Radiochromic Polyurethane (Presage™)





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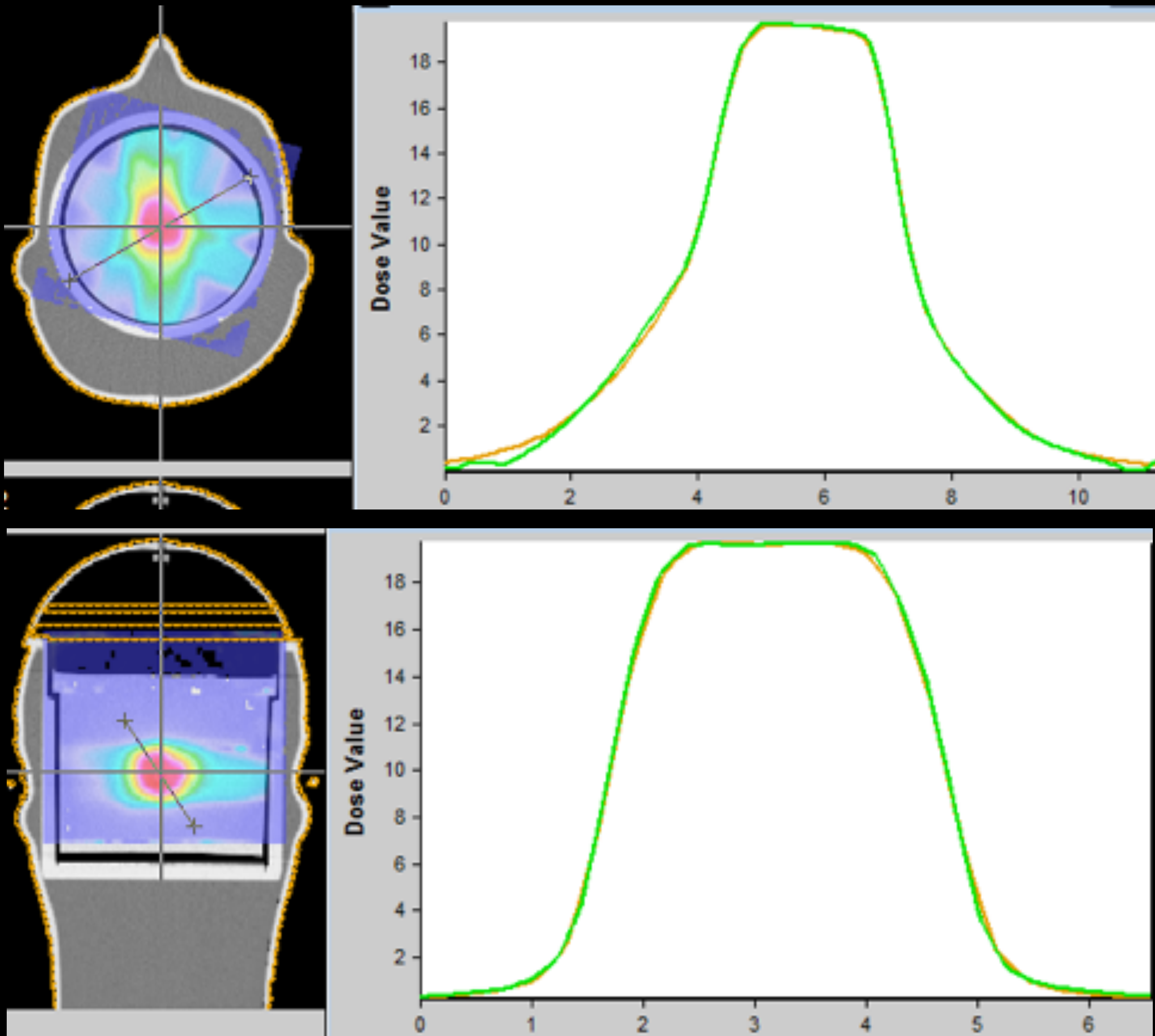
Measured dose vs. calculations



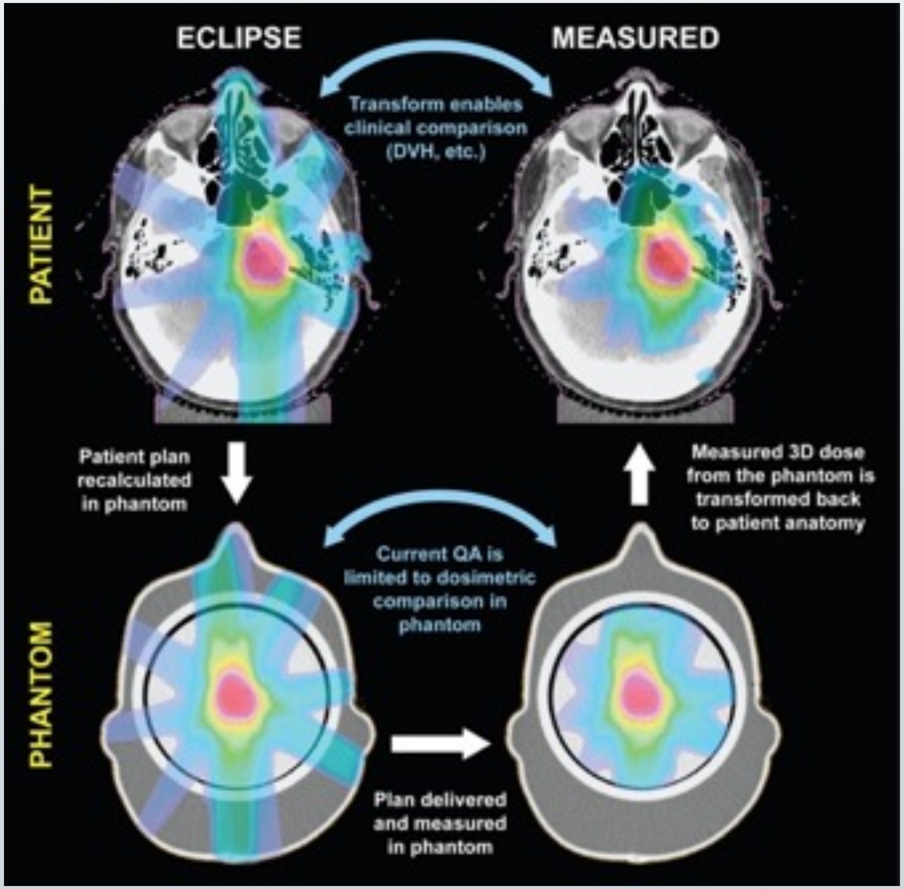
Eclipse

Presage

NDD Pass Rate = 97.6%

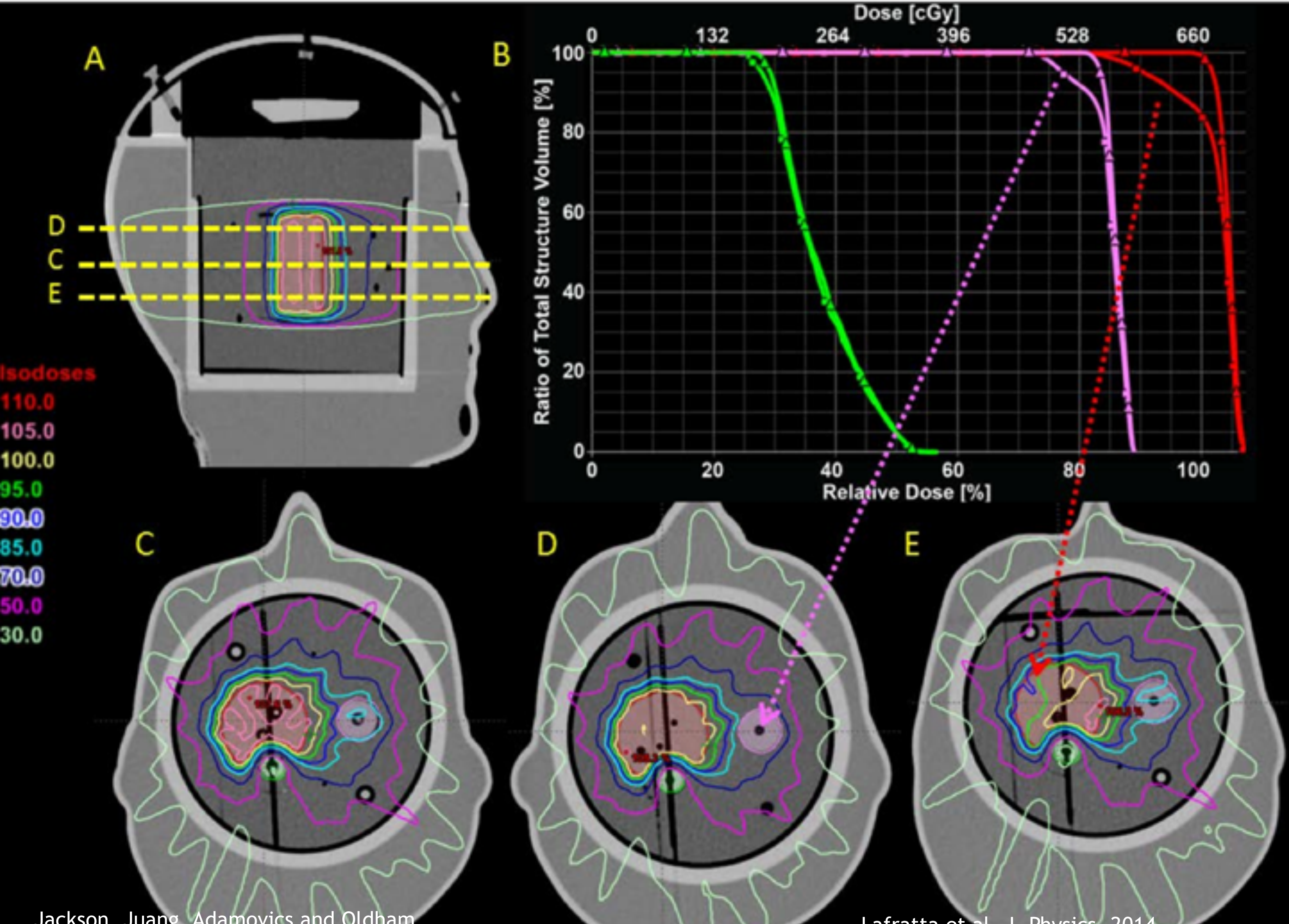
Courtesy M. Oldham, Duke Univ., 2012

The Transform Method



- Current dosimetry methods only allow for dose comparison in the phantom
- 3D dosimetry techniques allow the phantom dose distribution to be *transformed* into the patient geometry, facilitating clinical interpretation

Jackson, Juang, Adamovics and Oldham (2015) Physics in Medicine and Biology



Jackson, Juang, Adamovics and Oldham (2015) Physics in Medicine and Biology

Lafratta et al, J. Physics, 2014

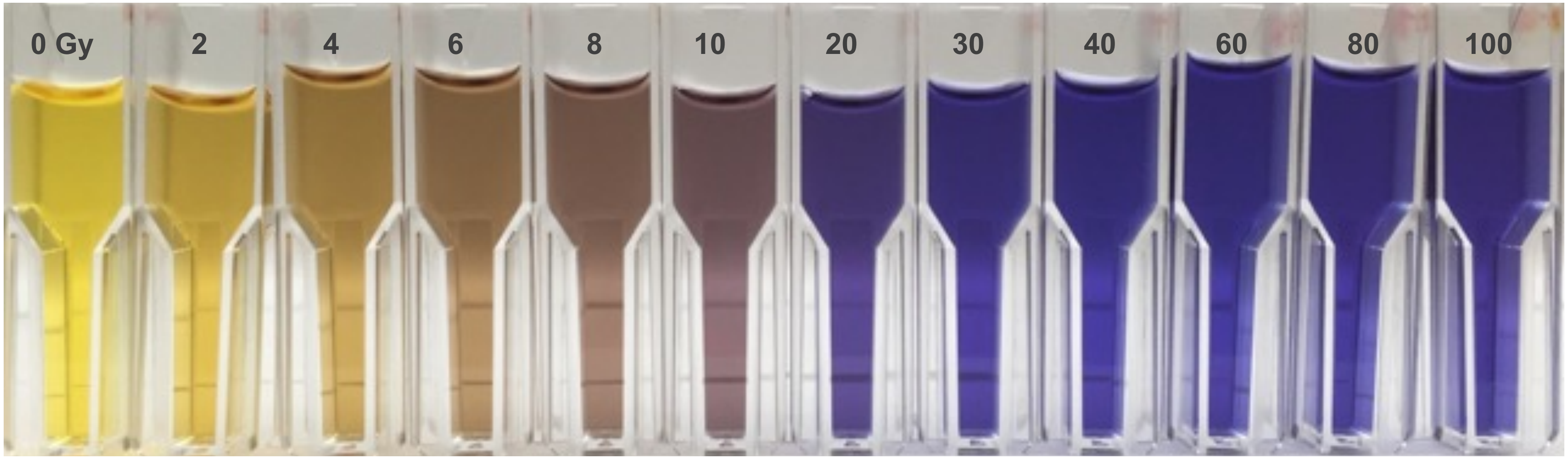
3D Dosimetry

Gels Investigated:

- Conventional Fricke gels: Iron(II) oxidation-based radiation reporting system
  - Our Fricke type gels shown in this presentation have greater optical and MR contrast compared to the conventional formulation
  - All dosimeters shown here were prepared in gelatin
- BANG^{TM} polymer gels
  - Standard formulation prepared by the manufacturer and poured into glass vessels of our design

Fricke gels

- Un-irradiated (Fe^{2+}) vs irradiated (Fe^{3+}) dosimeters
- Doses from 0 Gy to 100 Gy:



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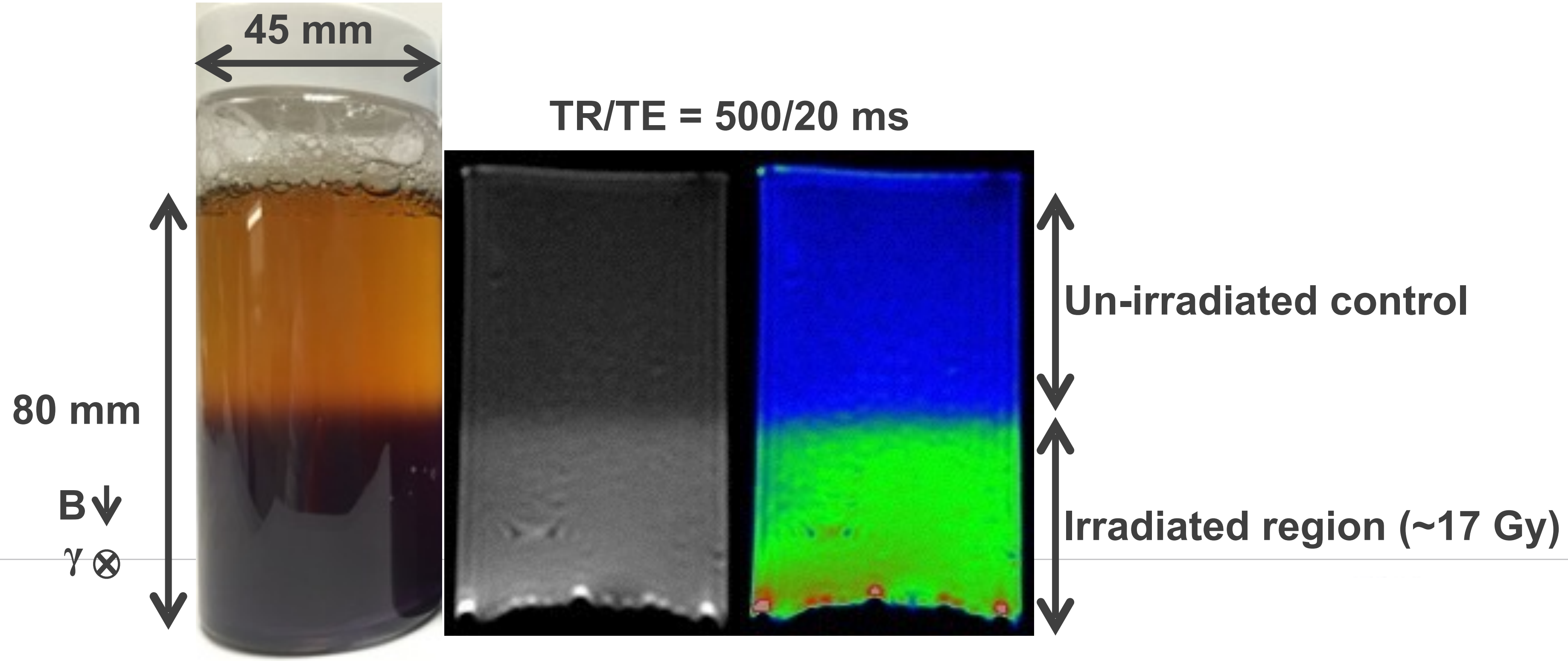
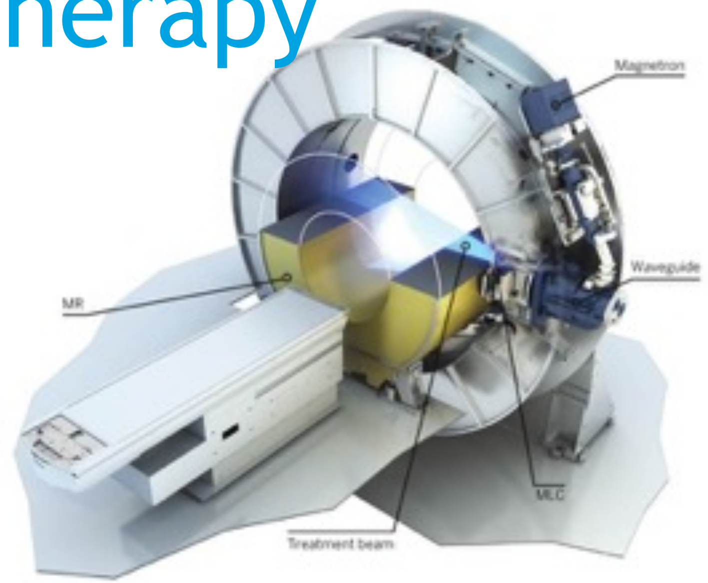
MR Imaging of Irradiated Gel

- Irradiated dosimeter with un-irradiated region shown below with T_1-weighted MR images in gray and RGB scale



MRI Guided Radiation Therapy



Purpose

Treat the patient while simultaneously imaging with a ‘conventional’ 1.5T diagnostic MRI

How

1. Mount the Linac on a rotatable gantry around the MRI magnet

    The radiation isocenter is at the centre of the MRI imaging volume

2. Modify the Linac to make it compatible with the MR environment
3. Modify the MRI system

    Minimize material in the beam path

    Minimize magnetic field at the Linac

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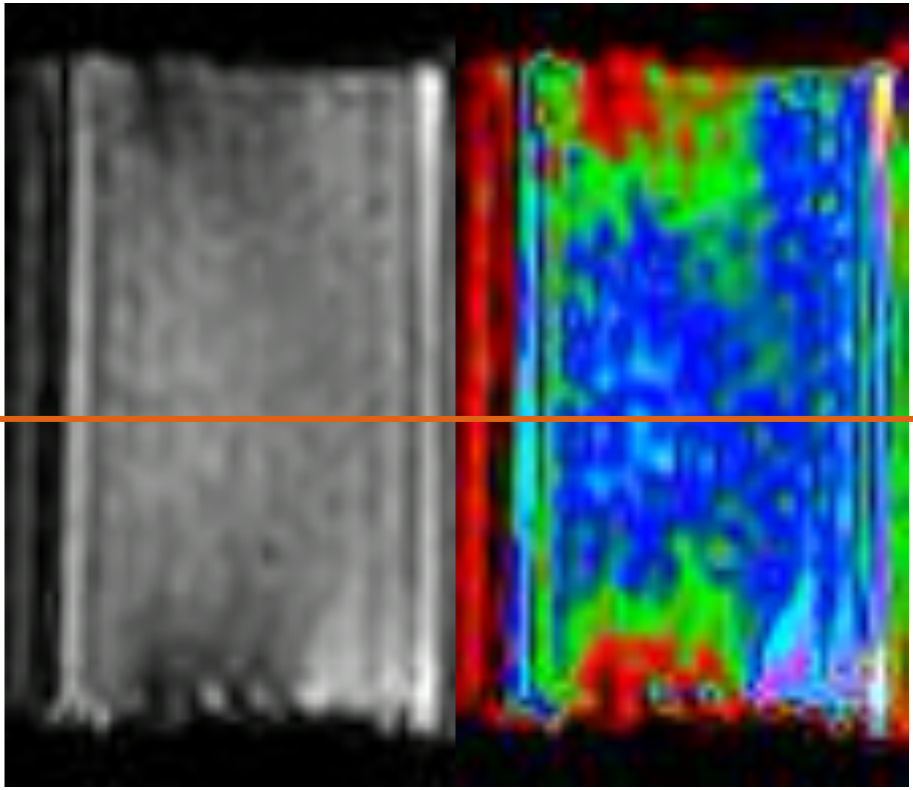
Change in irradiated region during beam-on can be seen with T_1-T2-weighted balanced-Fast Field Echo (b-FFE) MR images

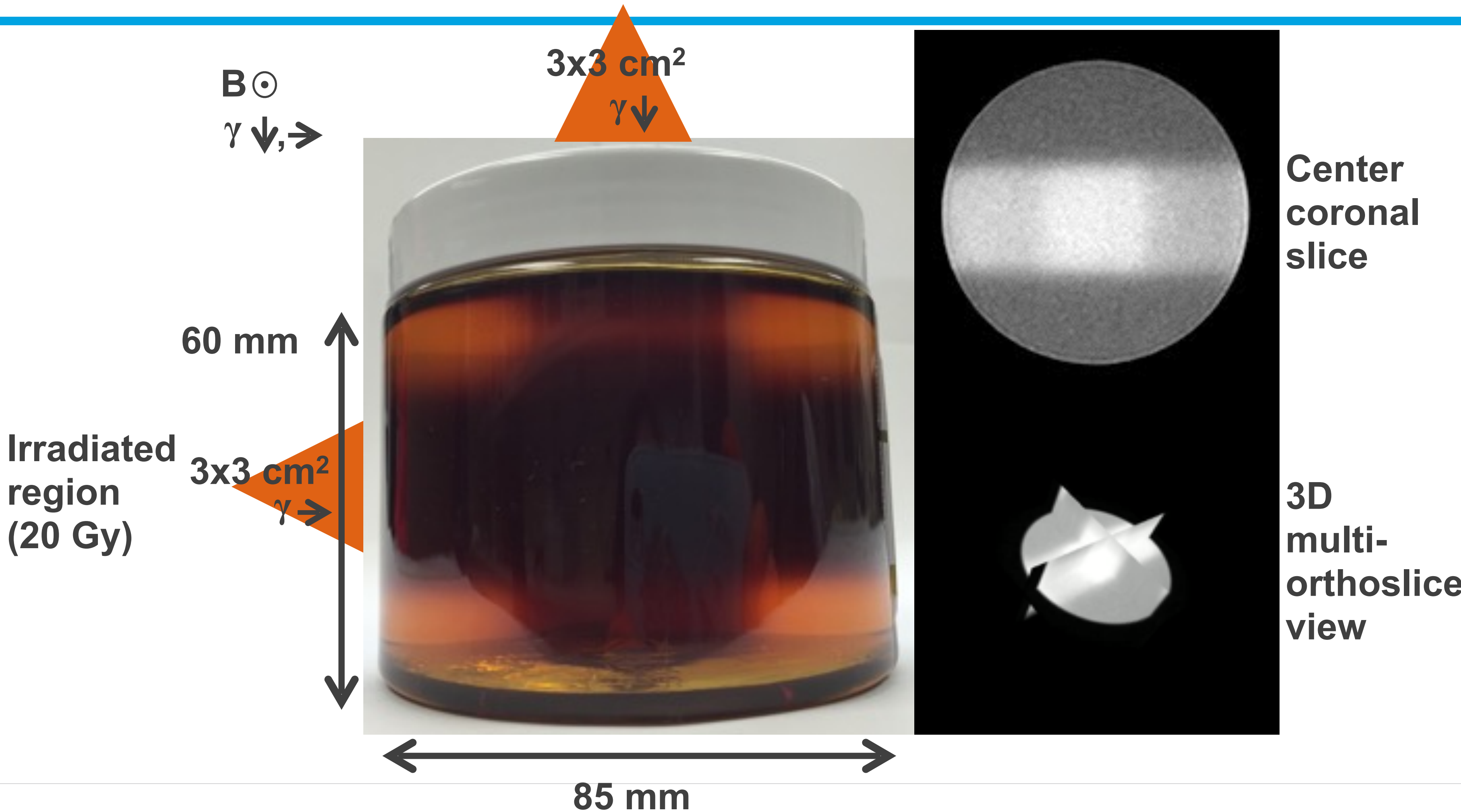
TR/TE = 5/2.4 ms

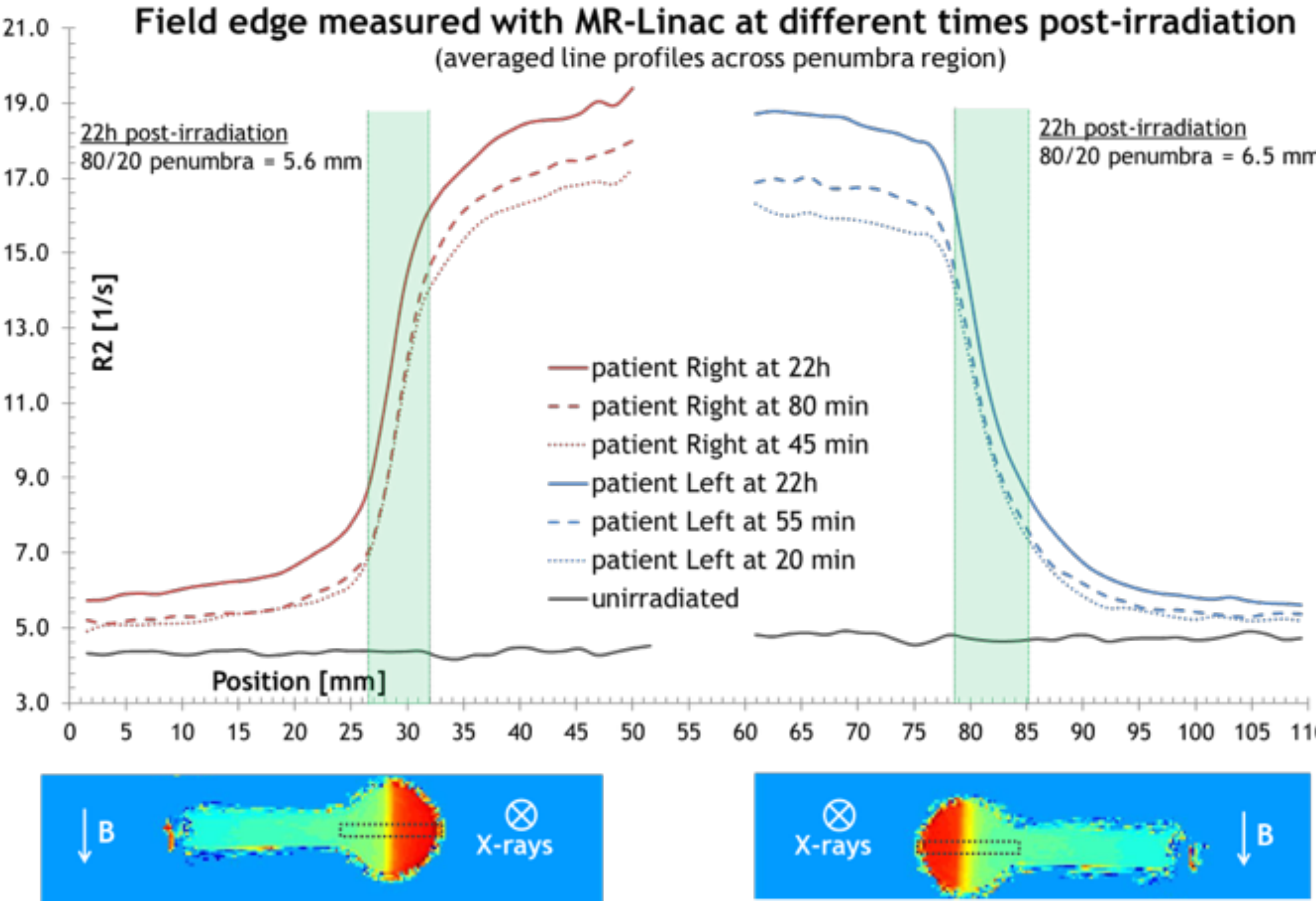


Irradiated region (~17 Gy)

1 f = 250 ms
200 fps

Irradiated region (10 Gy)





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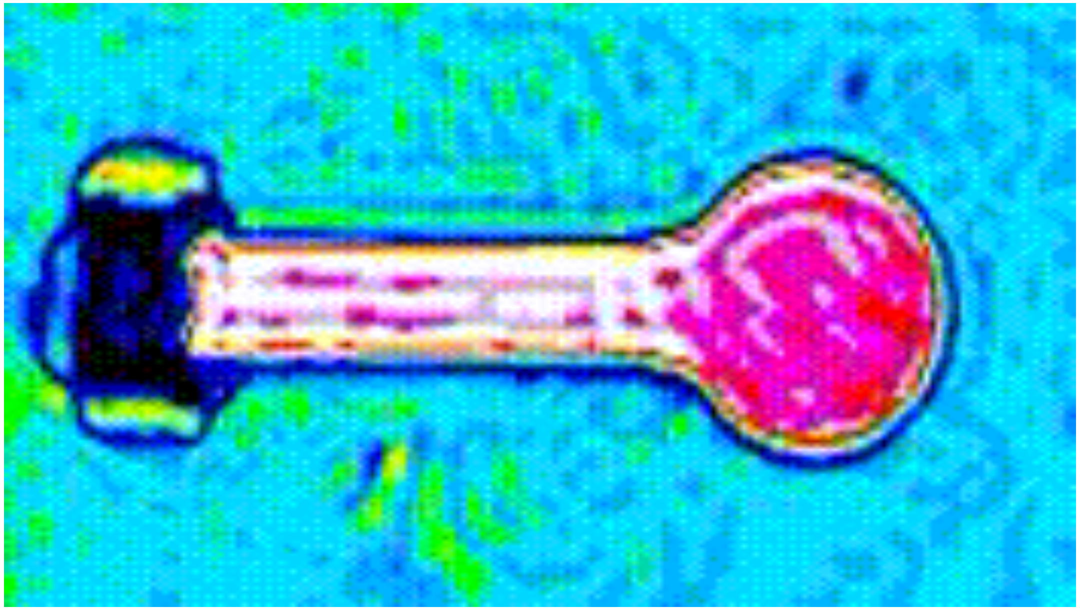
Real-time imaging of Penumbra

- Demonstrates immediate response of BANG gel to radiation
  - (Comparable to Fricke response with dose)



Summary

- 3D dosimetry offers benefits beyond those of conventional dosimeters
- 3D dosimeters can be optimized for conducting remote audits
- Gel dosimetry has potential in magnetic field environment

Thanks to:
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