

# Our Journey with DoseRT; Latest Clinical Results

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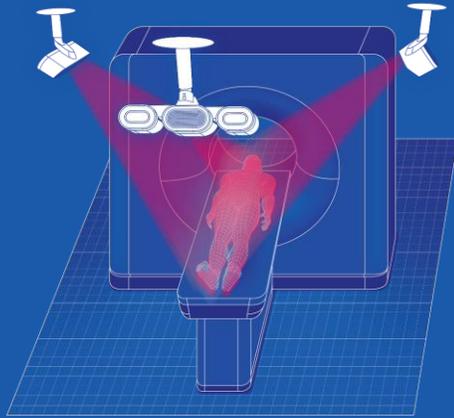
# Disclosures

## I Provide Physics Consultation Services

- Vision RT
- Varian

# OUR SGRT ECOSYSTEM

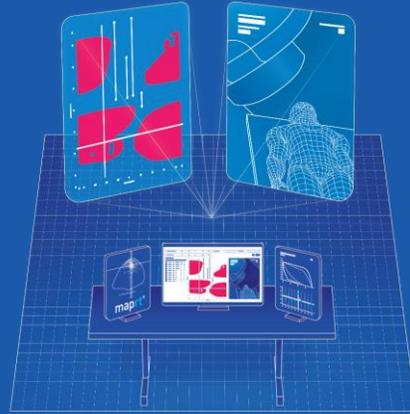
## SIM



4D AND BREATH HOLD  
CT

simrt™

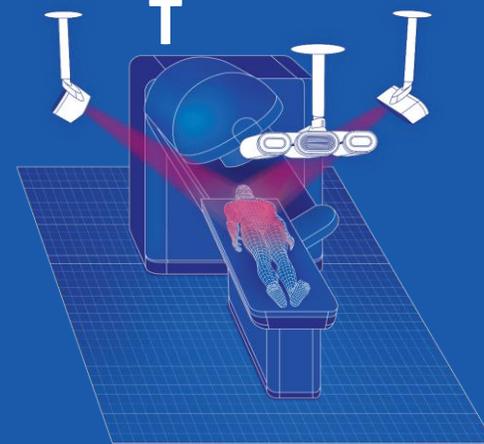
## PLAN



CLEARANCE  
MAPPING

maprt®

## TREA



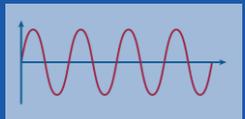
MOTION  
MANAGEMENT

alignrt®

## PATIENT ID



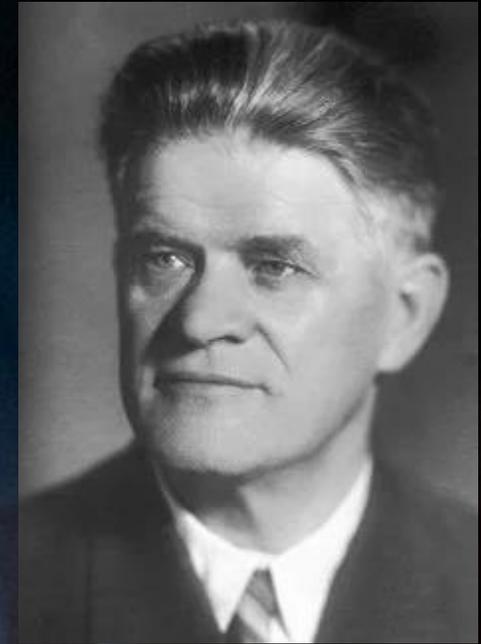
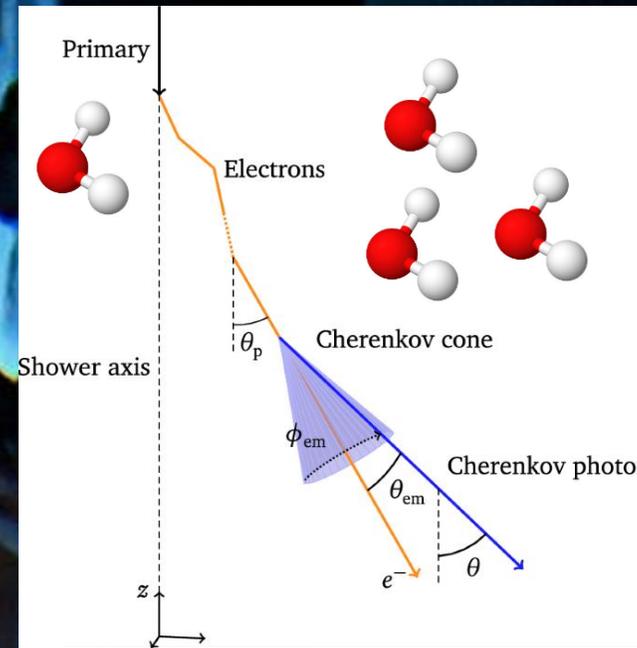
## GATING



## One Environment

- Fostering **Innovation**
- Improving the Patient **Experience**
- Integrating **Quality, Safety and Efficiency**

# Cherenkov Radiation

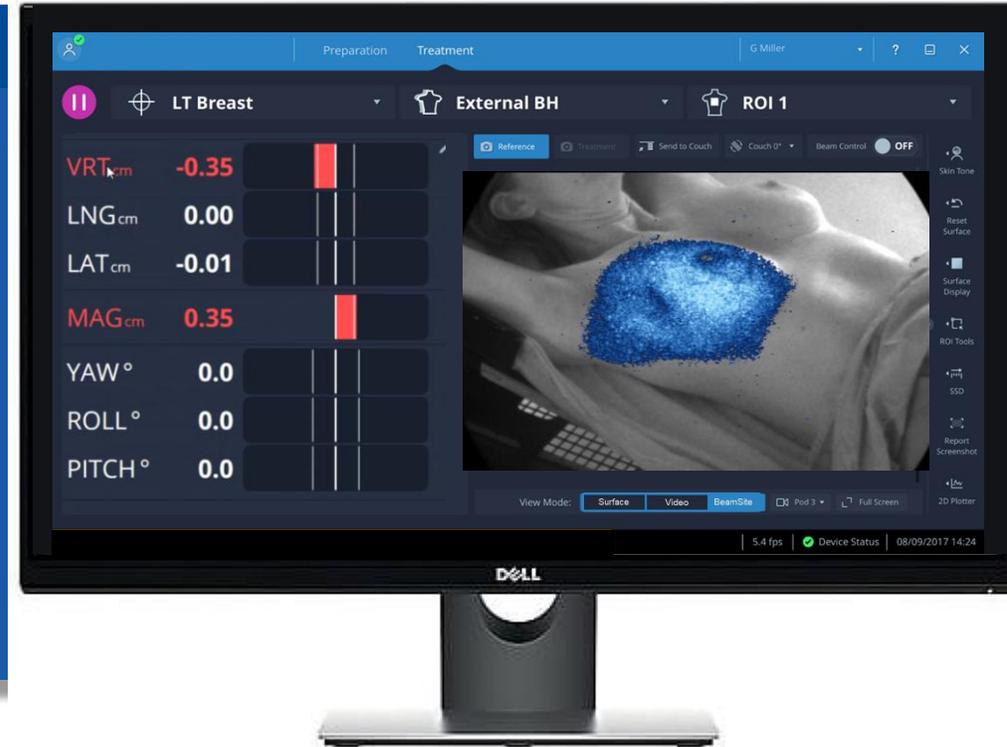
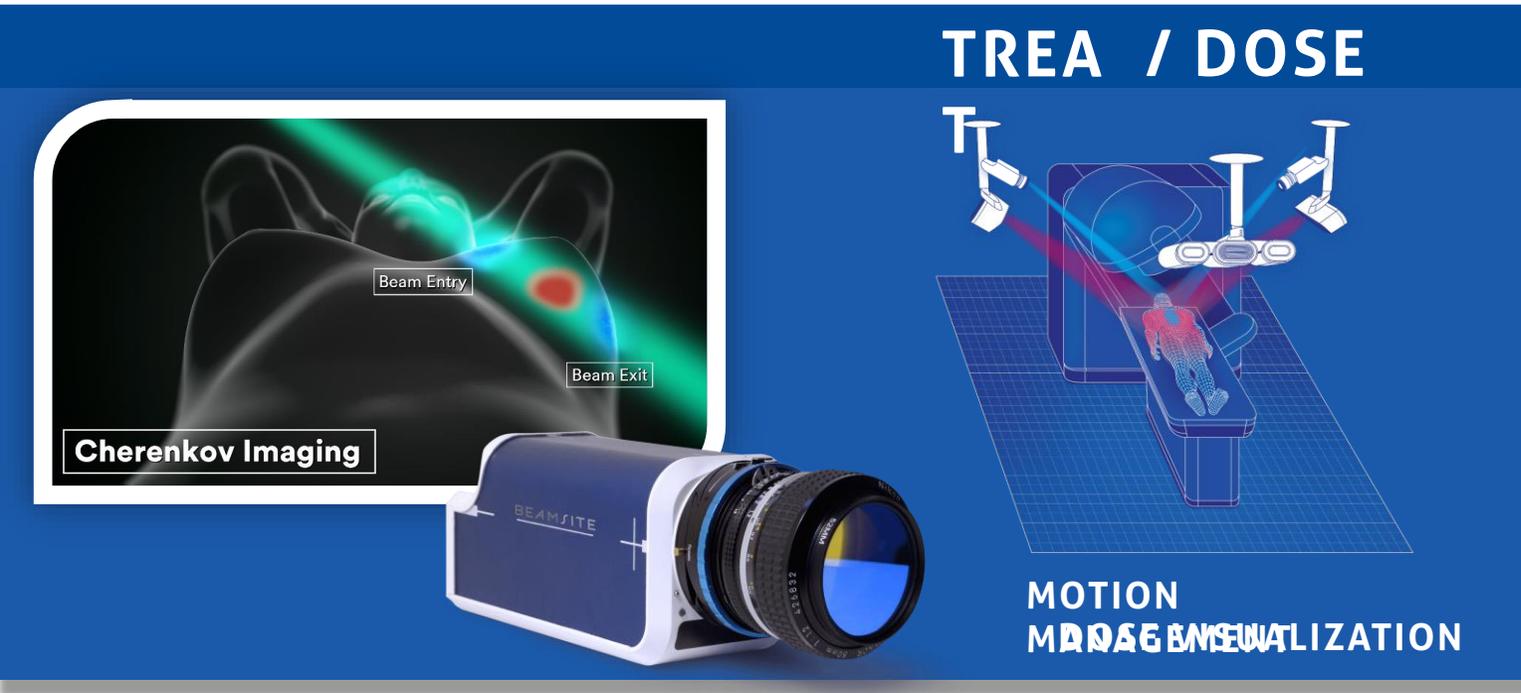


Pavel A Cherenkov

# VISUALIZE RADIATION THERAPY

ADDING A NEW DIMENSION TO PATIENT SAFETY AND MONITORING

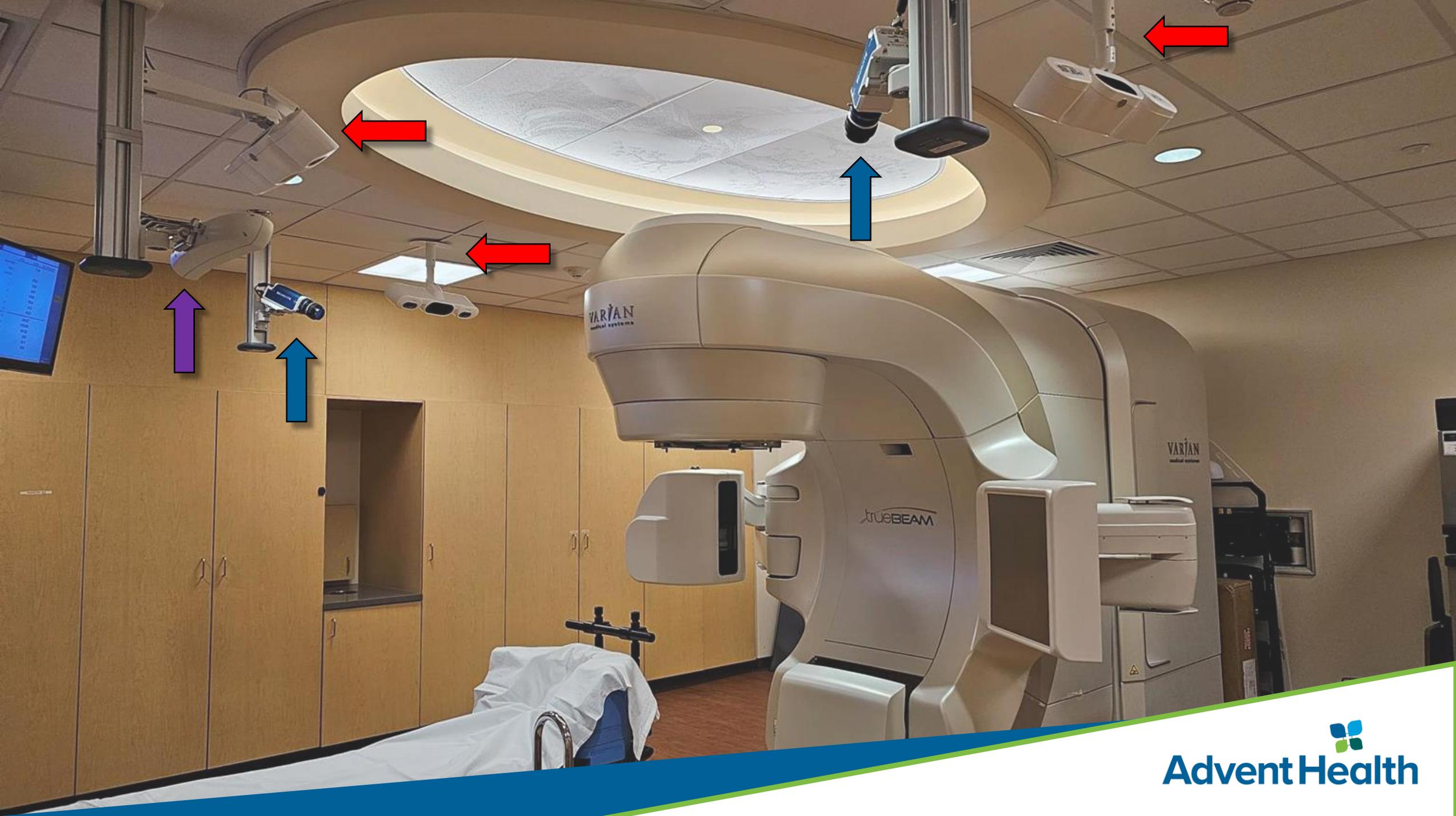
Watch the *Patient* and the *Beam*



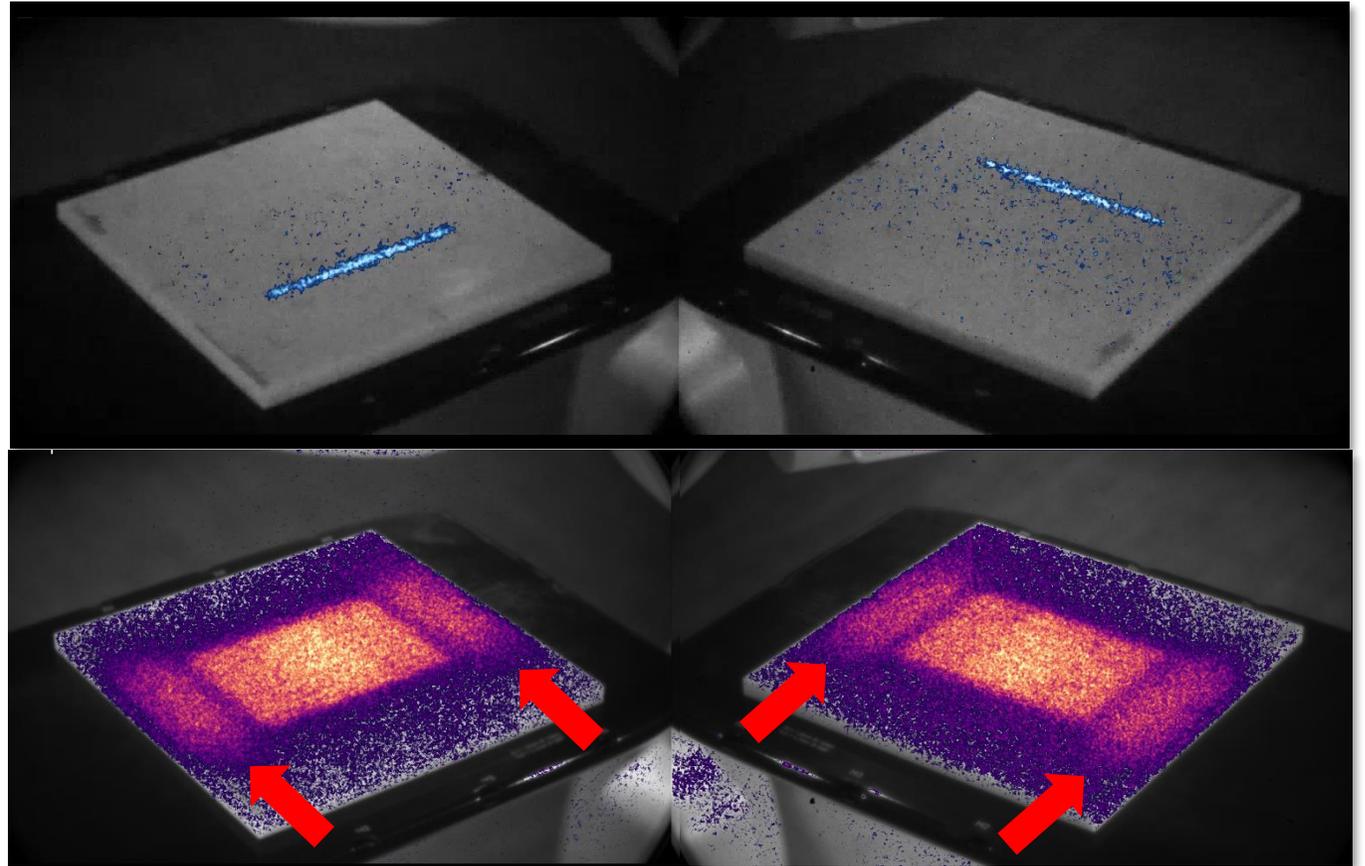
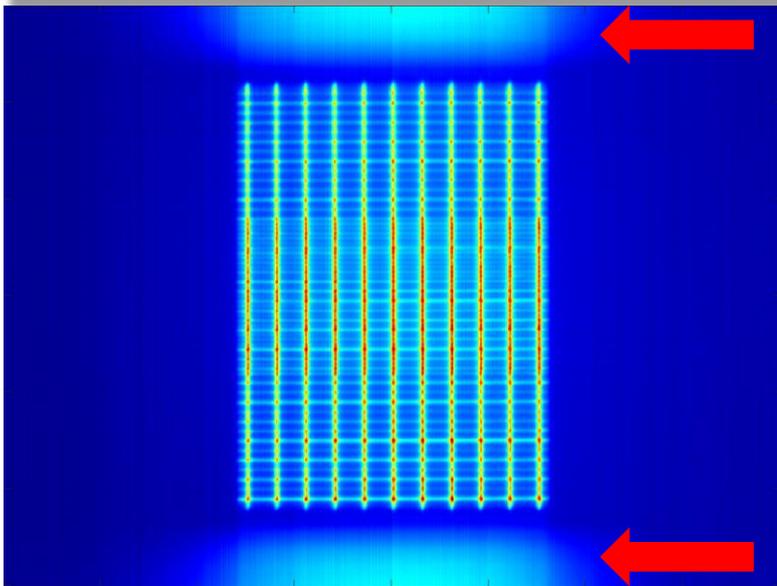
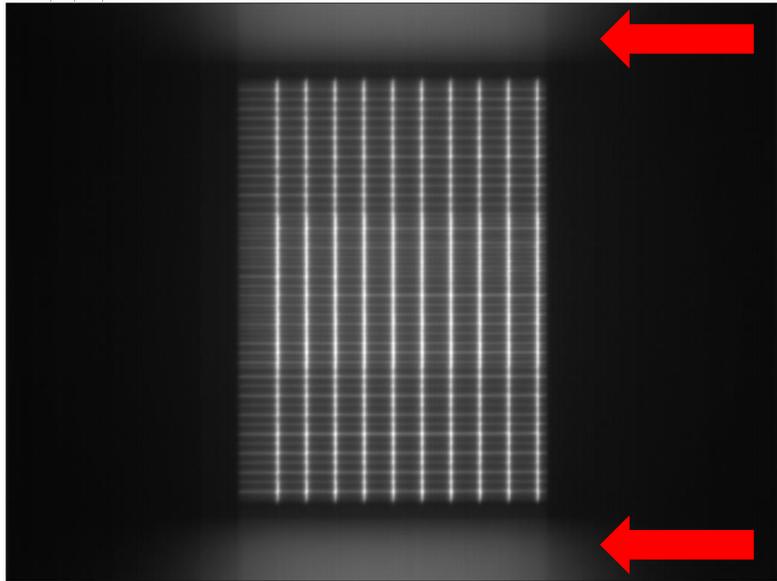
alignrt® dosert™  
Powered by BeamSite®

DoseRT enables simultaneous;

- Real Time Patient Monitoring
- Real Time Beam Visualization



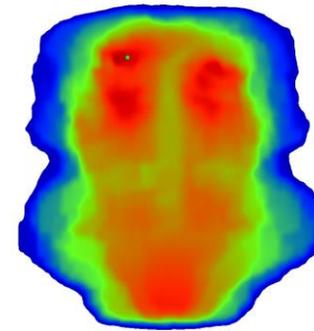
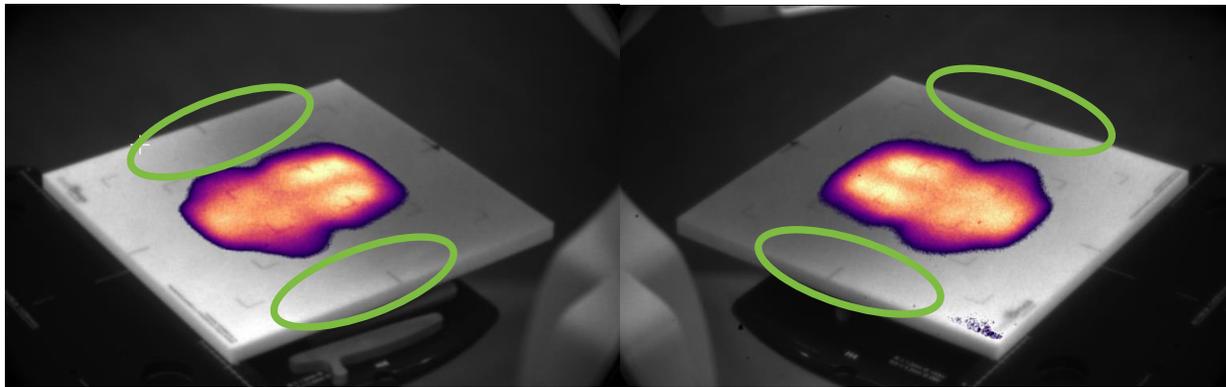
# VISUALIZATION OF LOW LEVELS OF STRAY RADIATION



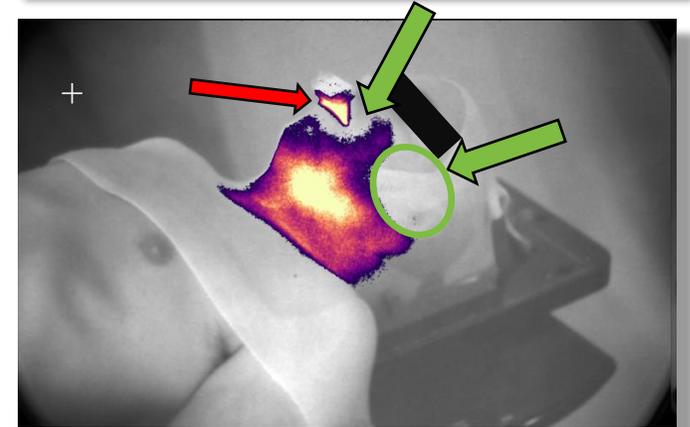
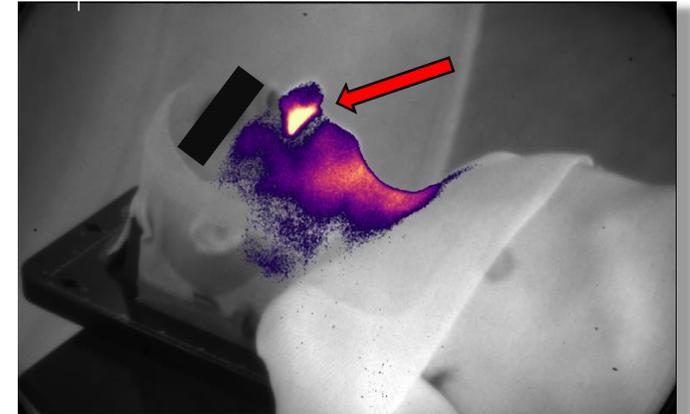
Varian CTB updated in Customer Release Note (2013)  
P/N 100020576-10

# CASE STUDY: PATIENT QUALITY ASSURANCE

High modulation factor verification prior to treatment delivery and verification of desired avoidance sectors during treatment delivery...



Perform Standard QA  
(Pre Tx Verification)



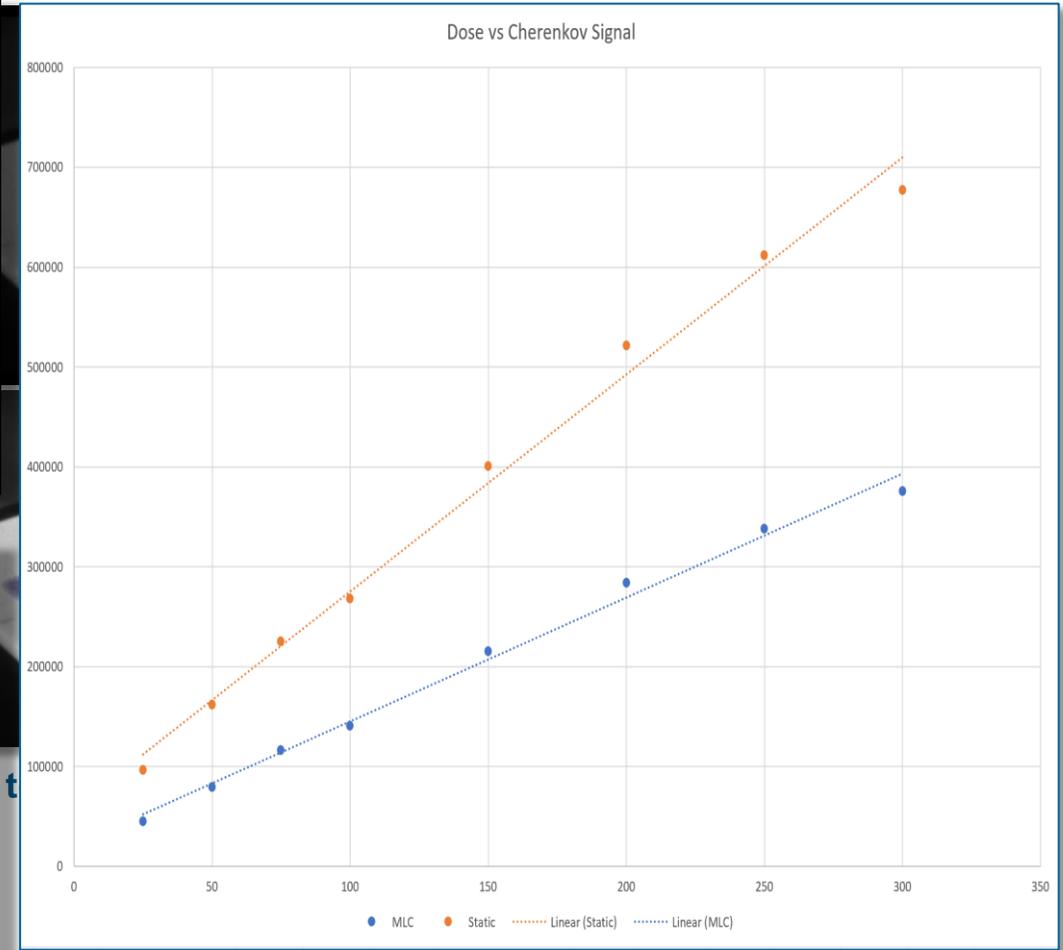
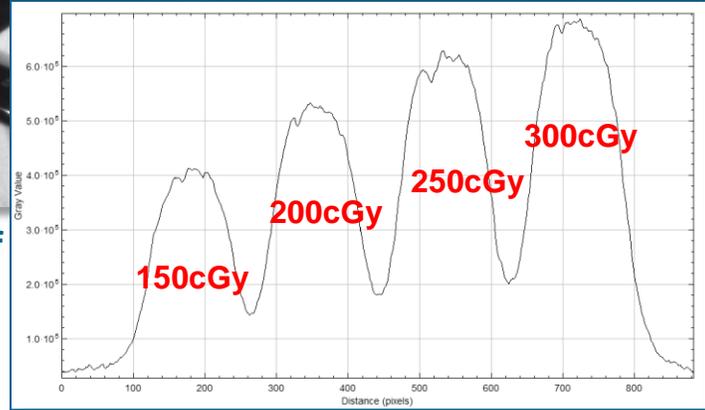
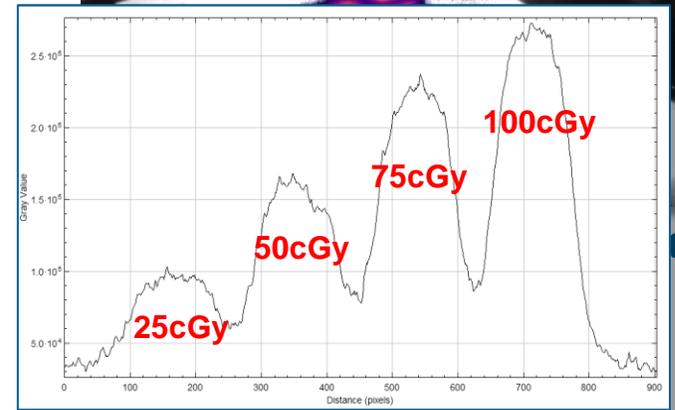
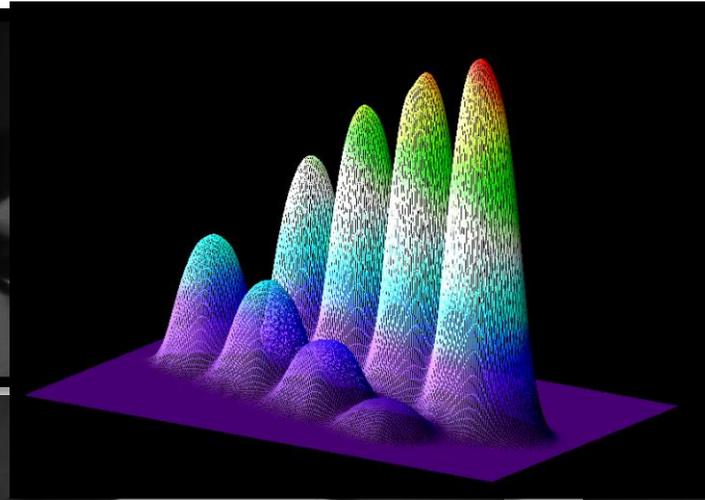
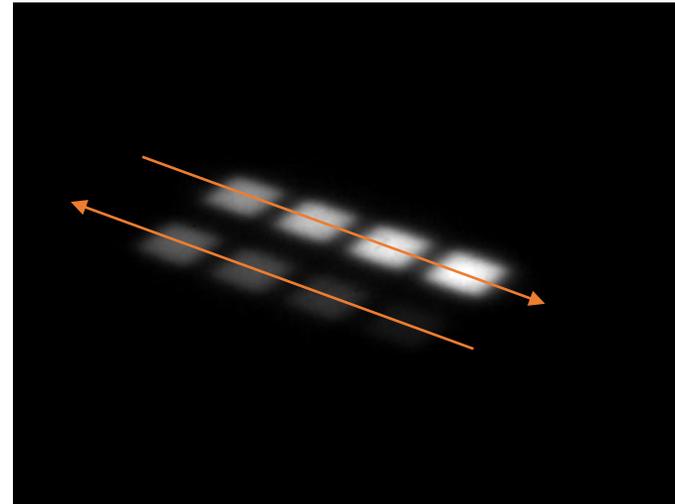
Treatment Delivery

## Visual Verification of Suspected Over Modulation of Plan

(Check can be performed in QA mode prior to plan finalization)

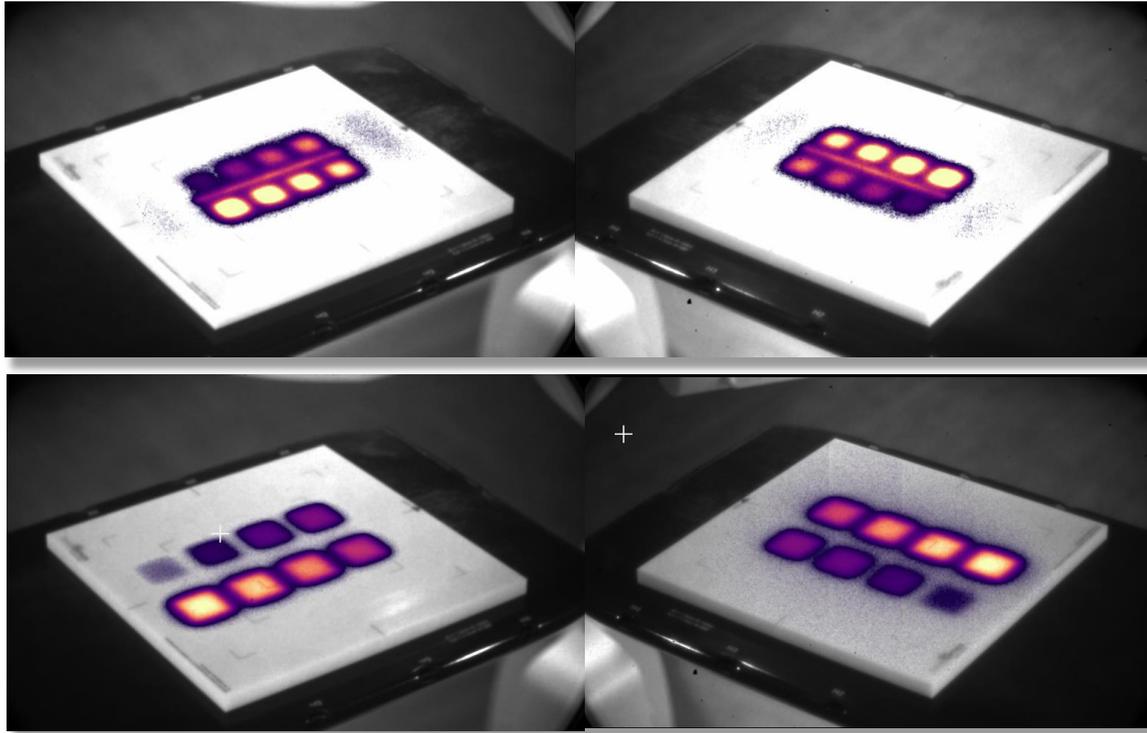
- Confirmation during delivery of planning techniques like **avoidance sectors** for VMAT
- Seek to understand **“anomalous”** signal in composite imaging

# POTENTIAL QUANTITATIVE APPLICATIONS

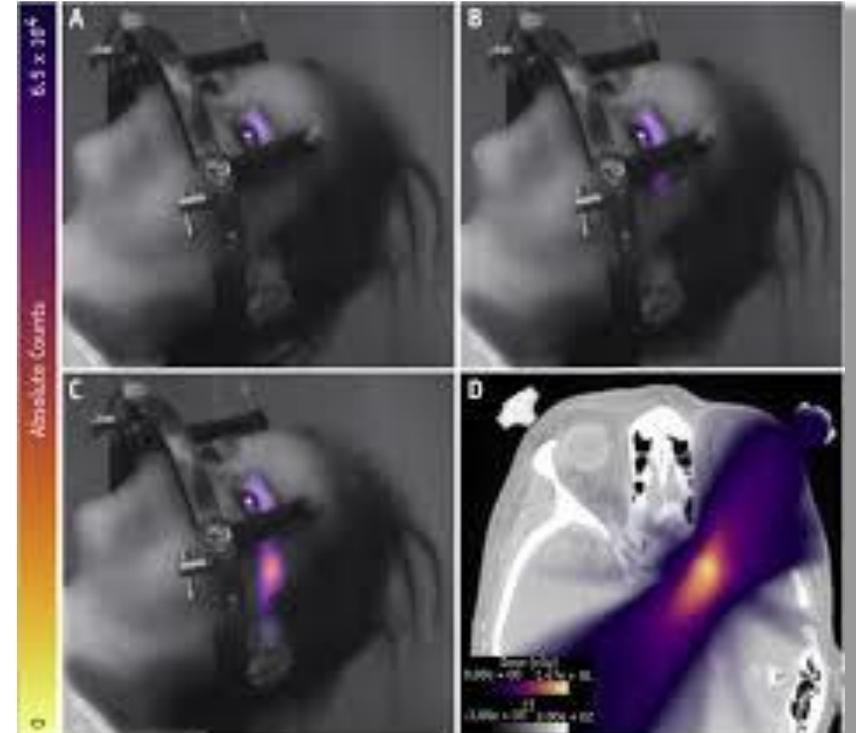


❖ Ilya Frank and Igor Tamm worked out the mathematics for this and shared the 1958 Nobel Prize with Cherenkov

# POTENTIAL QUANTITATIVE APPLICATIONS



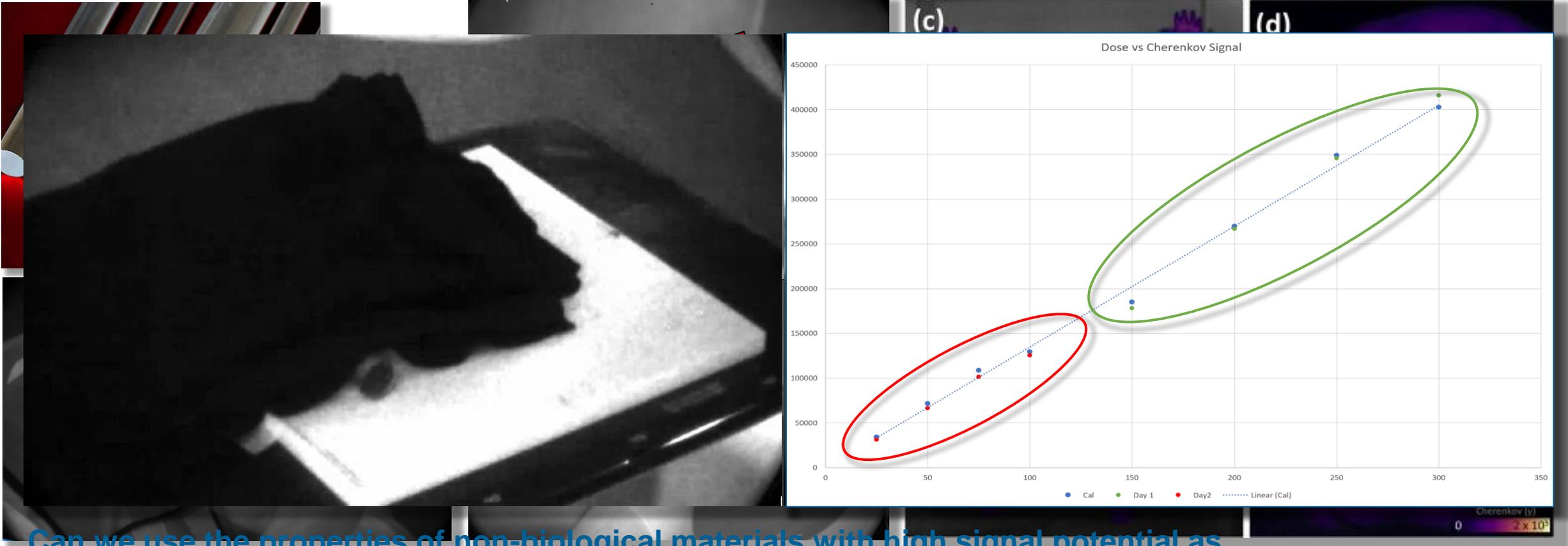
\*The amount of Cherenkov light emitted is proportional to the dose delivered to the medium



Tendler II et al. Experimental Observed Cherenkov Light Generation in the Eye During Radiation Therapy. *Int J Radiat Oncol Biol Phys.* 2020 Feb 1; 106(3) 422-429

Can we potentially use this as a way of verifying dose for very small field as part of our pretreatment checks when only coarse detector arrays are available?

# POTENTIAL QUANTITATIVE APPLICATIONS



Can we use the properties of non-biological materials with high signal potential as real-time dosimeters?

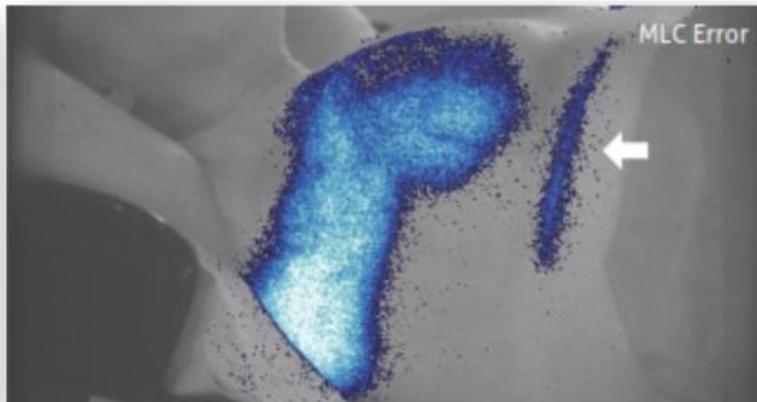
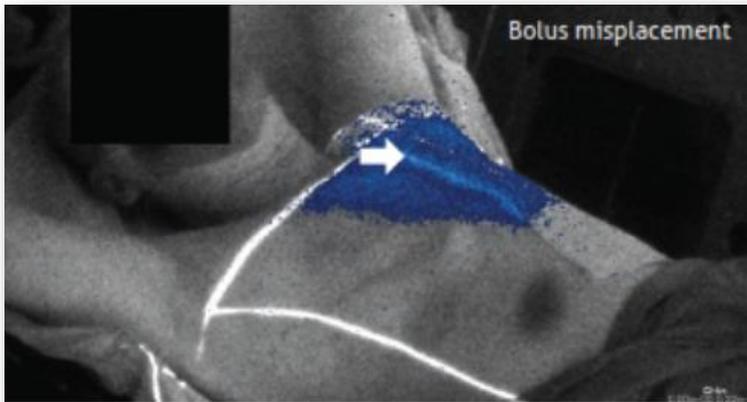
Jarvis LA et al. Initial Clinical Experience of Cherenkov Imaging in External Beam Radiation Therapy Identifies Opportunities to Improve Treatment Delivery. *Int J Radiat Oncol Biol Phys.* 2021 Apr 1;109(5):1627-1637

# BENEFITS OF CHERENKOV IMAGING

Initial experience\* suggests ~10% of patients experience compliance, setup, plan or habitus issues;

- Chin irradiated during supraclavicular fields
- Arm irradiated during tangential breast fields
- Bolus misplacement
- Open MLC leaves

DoseRT™ can help detect, and prevent these cases



\* Initial experience with 60 patients  
References available upon request

International Journal of **ASTRO**  
Radiation Oncology • Biology • Physics  
www.ijro.net

Physics Contribution

**Initial Clinical Experience of Cherenkov Imaging in External Beam Radiation Therapy: Opportunities to Improve Patient Compliance**

Lesley A. Jarvis, MD, PhD,\* Raci Michael Jermyn, PhD,<sup>1</sup> Petr Bruz Irwin I. Tendler, PhD,<sup>1</sup> Benjamin David J. Gladstone, ScD,<sup>\*,1</sup> Phil Bassem I. Zaki, MD,<sup>\*,1</sup> and Brian W. Pogue, PhD<sup>\*,1</sup>

*\*Department of Medicine, Section of Radiation Oncology, Dartmouth Medical Center, Hanover, New Hampshire; and <sup>1</sup>Thayer School of Engineering, Dartmouth College, Hanover, New Hampshire*

Received Jan 5, 2020. Accepted for publication Nov 10, 2020.

**Purpose:** The value of Cherenkov imaging as a real-time verification tool for external beam radiation therapy (EBRT) treatment delivery was evaluated in a 60-patient cohort during routine radiation therapy. **Methods and Materials:** Cherenkov cameras were used to monitor radiation therapy delivery for various sites (breast, lung, prostate, and head and neck), multiple fractions were imaged, with the mean distance to the target and the mean lateral distance to the target were calculated with a mean distance to the target. **Results:** In breast treatments, Cherenkov imaging of the breast, arm, or the chin was found nonconformant with the treatment plan. For all 199 imaged by the first day of treatment (with only 7.5% of treatment plans), the value of imaging dose through Cherenkov imaging also was able to assess field conformity. **Conclusion:** Cherenkov imaging confirmed the value of Cherenkov imaging as a real-time verification tool for EBRT treatment delivery.

Corresponding author: Lesley A. Jarvis, MD, PhD, E-mail: jarvis@dartmouth.edu

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Disclosures: L.A.J. and B.W.P. have a financial interest in the Cherenkov camera technology used in this study and in the future. They also have a conflict of interest management plan in place at Dartmouth-Hitchcock Medical Center, which is subject to review by the research integrity before publication. Patent pending application no. 62/974,120. B.I.Z. has a patent pending application no. 62/974,120. M.J. and P.B. are employees of the Dartmouth-Hitchcock Medical Center.

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Physics Contribution

**Cherenkov Video Imaging Allows for the First Real-time Visualization of Radiation Therapy in Real Time**

Lesley A. Jarvis, MD, PhD,<sup>\*,1</sup> Rongxiao Zhang, BS,<sup>1</sup> David J. Gladstone, ScD,<sup>\*,1</sup> Shudong Jiang, PhD,<sup>1</sup> Whitney Hitchcock,<sup>1</sup> Oscar D. Friedman,<sup>1</sup> Adam K. Glaser, BE,<sup>1</sup> Michael Jermyn, PhD,<sup>1</sup> and Brian W. Pogue, PhD<sup>\*,1</sup>

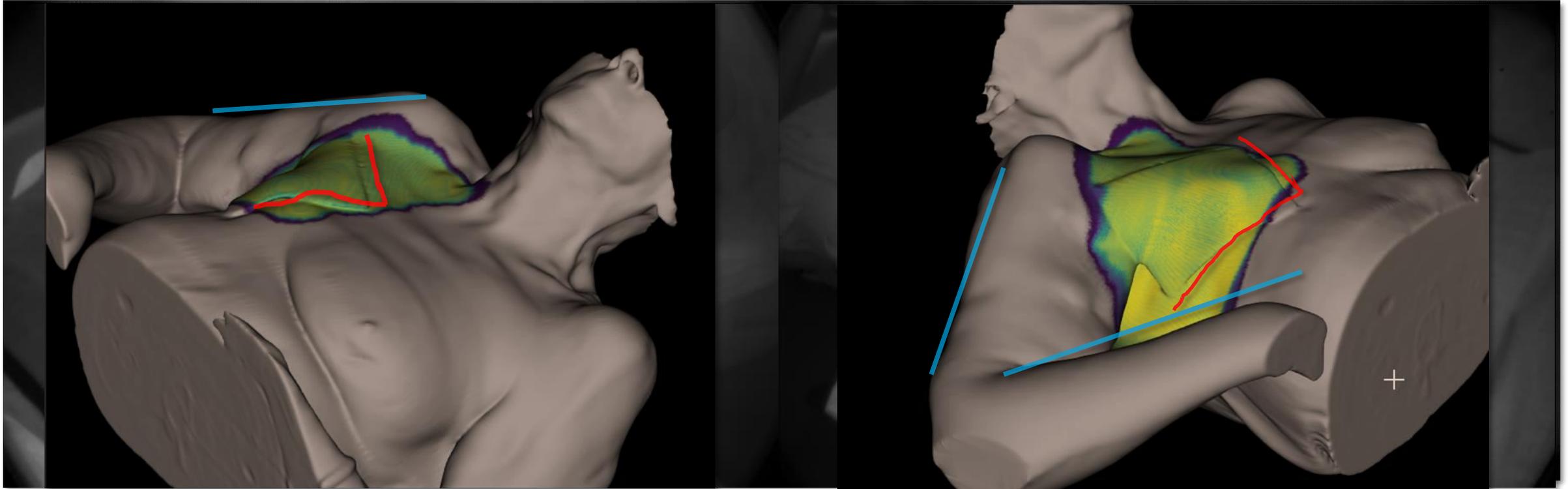
*\*Department of Medicine, Geisel School of Medicine at Dartmouth College, Hanover, New Hampshire; <sup>1</sup>Harris Cotton Cancer Center at the Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire; <sup>2</sup>Department of Physics and Astronomy and <sup>3</sup>Thayer School of Engineering, Dartmouth College, Hanover, and <sup>4</sup>Geisel School of Medicine at Dartmouth College, Hanover, New Hampshire*

Received Oct 29, 2013, and in revised form Jan 1, 2014. Accepted for publication Jan 27, 2014.

**Summary:** Cherenkov light imaging shows radiation therapy in real time and can be viewed at the treatment console or as a video after treatment delivery. **Methods and Materials:** An intensified charge-coupled device (CCD) camera was synchronized to the 3.25-μs radiation pulses of the clinical linear accelerator with the intensifier set to > 100. Cherenkov images were acquired continuously (2.8 frames/s) during fractionated whole-breast irradiation with each frame an accumulation of 100 radiation pulses (approximately 5 monitor units). **Results:** The first patient images ever created are used to illustrate that Cherenkov emission can be visualized as a video during conditions typical for breast radiation therapy, even with complex treatment plans, mixed energies, and modulated treatment fields. Images were generated correlating to the superficial dose received by the patient and potentially the location of the resulting skin reactions. Major blood vessels are visible in the image, providing the potential to use these as biological landmarks for improved geometric accuracy. The potential for this system to detect radiation therapy misadministrations, which can result from hardware malfunction or patient positioning setup errors during individual fractions, is shown. **Conclusions:** Cherenkov imaging is a unique method for visualizing surface dose resulting in real-time quality control. We propose that this system could detect radiation therapy errors in everyday clinical practice at a time when these errors can be corrected to result in improved safety and quality of radiation therapy. © 2014 Elsevier Inc.



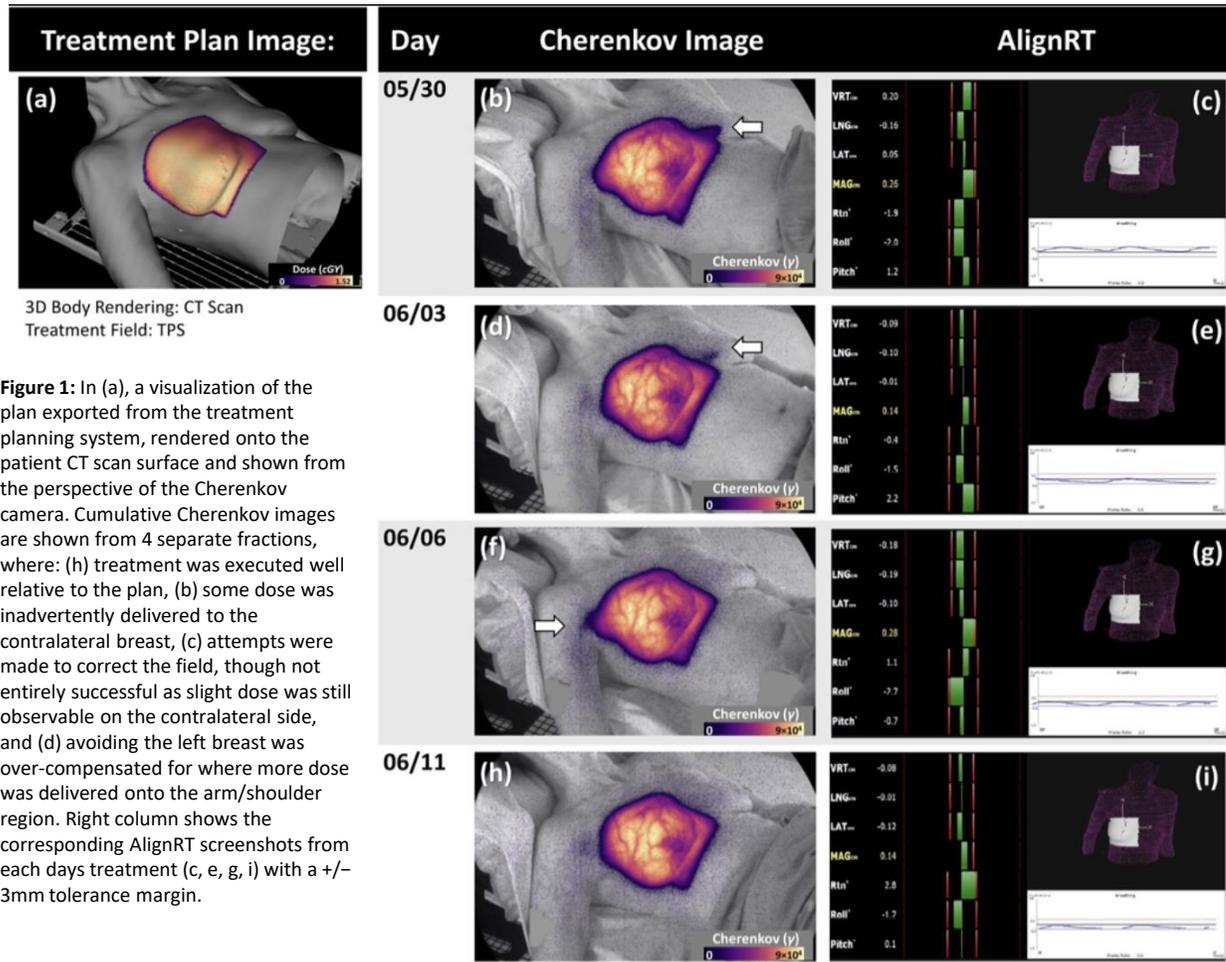
# QUALITY AND SAFETY: LIMB SPARING & BOLUS PLACEMENT



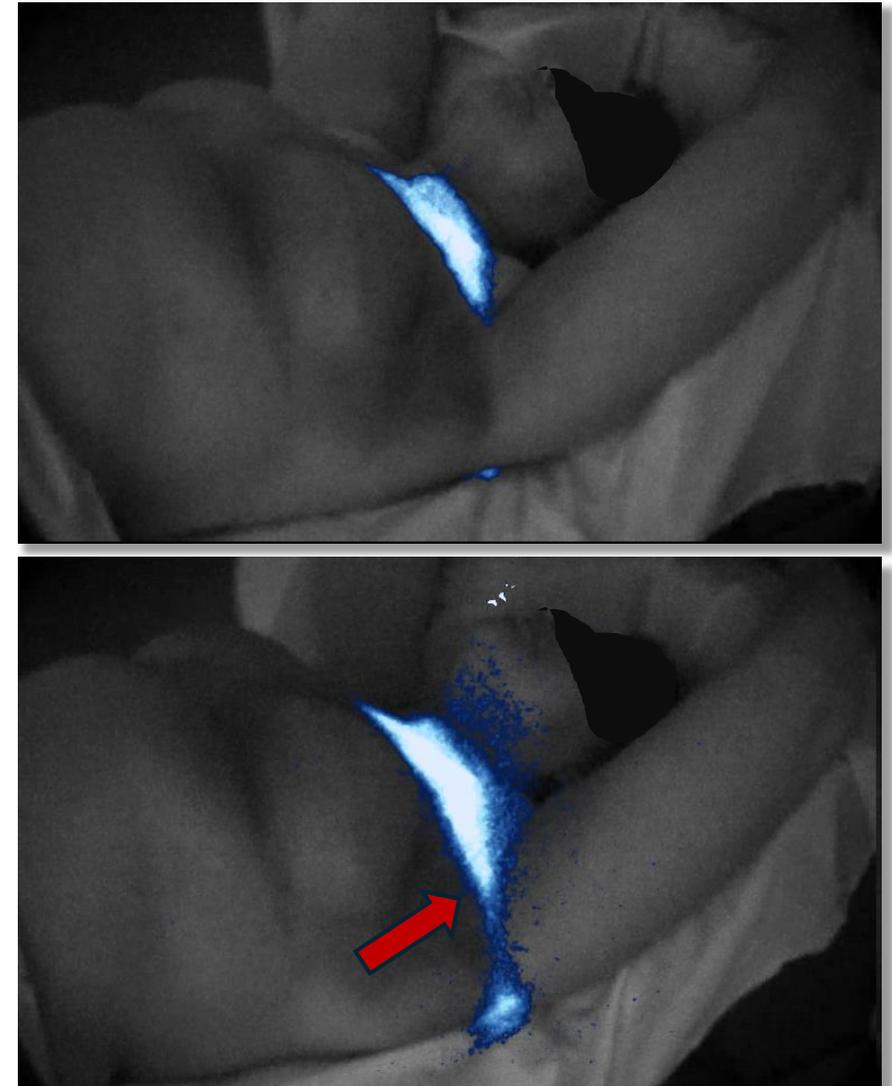
- 99 Year Old Female undergoing IMRT treatment for fungating mass in left intact breast / axilla
- Challenges from simulation
  - Partial bolus coverage of mass and involved skin margin
  - Bubble wrap spacer to address skin fold due to inability to raise ipsilateral arm
- Visual verification of treatment dose initiated from fraction 1 of treatment

# CASE STUDY: PATIENT ALIGNMENT

\* Sub-Optimal Treatment Delivery...



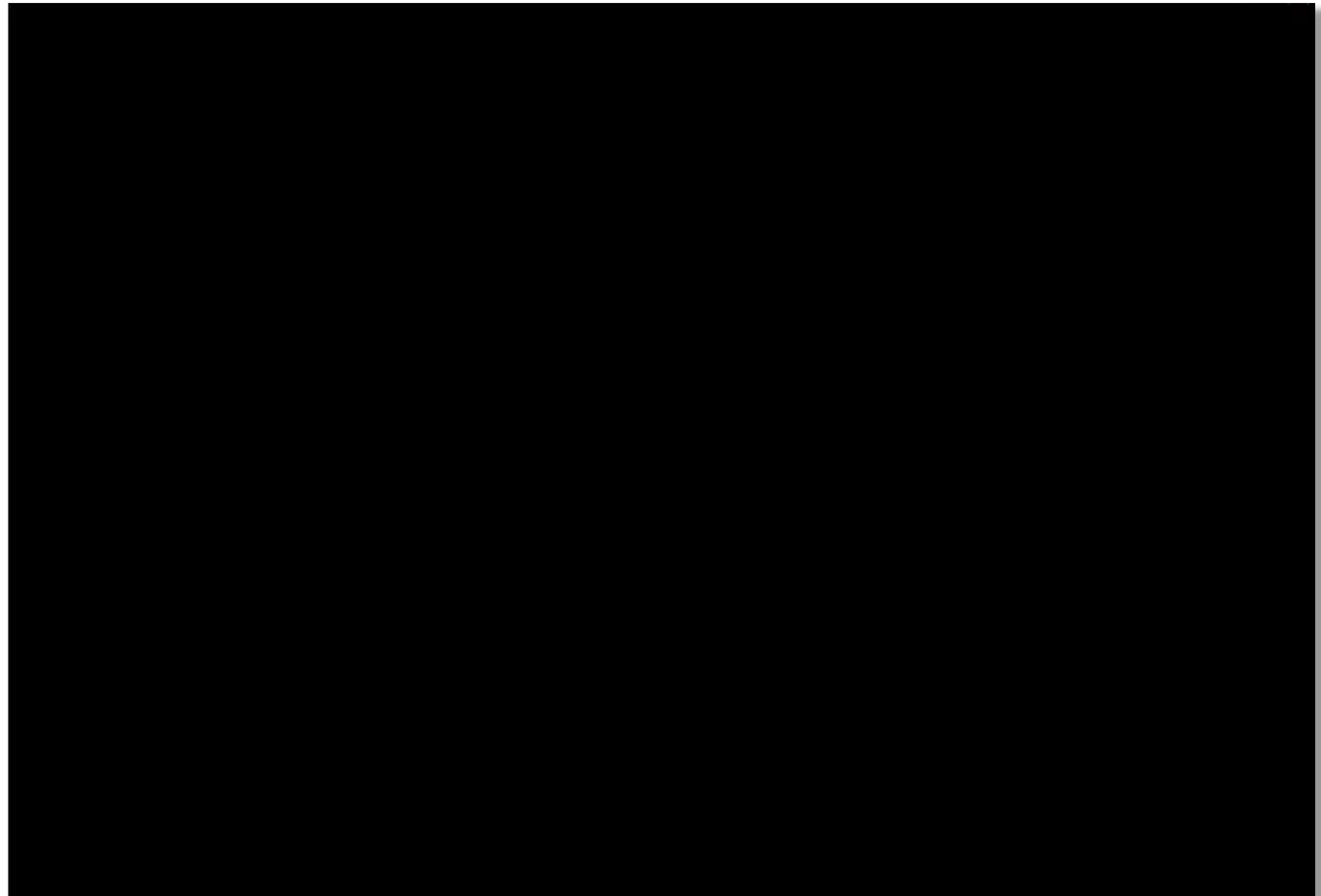
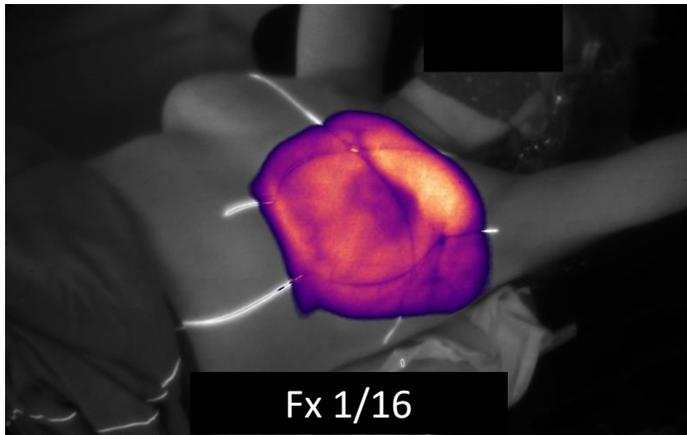
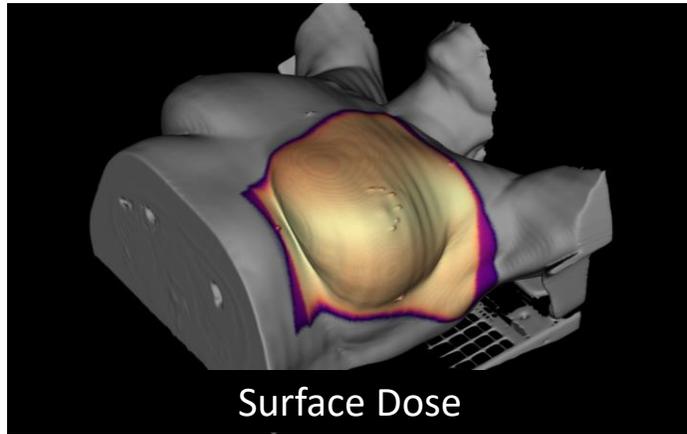
**Figure 1:** In (a), a visualization of the plan exported from the treatment planning system, rendered onto the patient CT scan surface and shown from the perspective of the Cherenkov camera. Cumulative Cherenkov images are shown from 4 separate fractions, where: (h) treatment was executed well relative to the plan, (b) some dose was inadvertently delivered to the contralateral breast, (c) attempts were made to correct the field, though not entirely successful as slight dose was still observable on the contralateral side, and (d) avoiding the left breast was over-compensated for where more dose was delivered onto the arm/shoulder region. Right column shows the corresponding AlignRT screenshots from each days treatment (c, e, g, i) with a +/- 3mm tolerance margin.



Jarvis LA et al. Initial Clinical Experience of Cherenkov Imaging in External Beam Radiation Therapy Identifies Opportunities to Improve Treatment Delivery. *Int J Radiat Oncol Biol Phys.* 2021 Apr 1;109(5):1627-1637

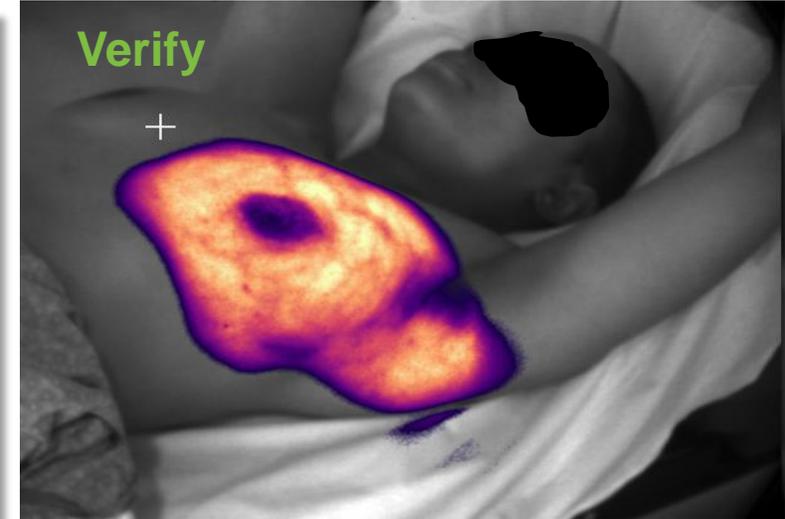
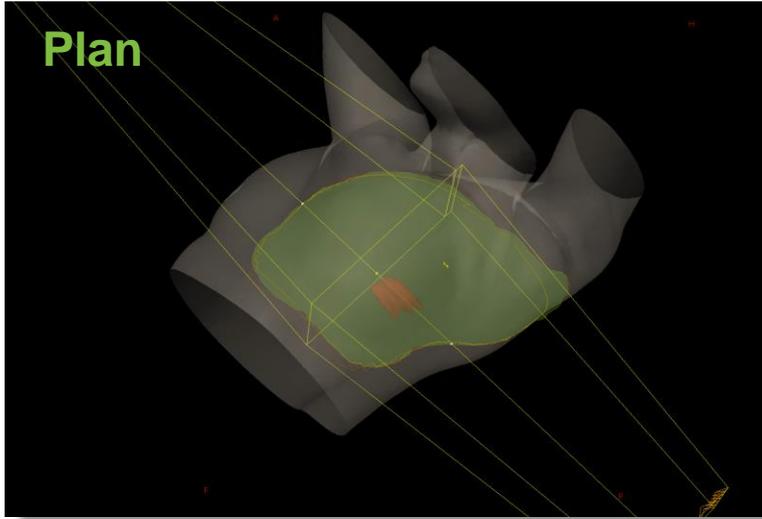
# CASE STUDY: PATIENT ALIGNMENT

\* Sub-Optimal Treatment Delivery...

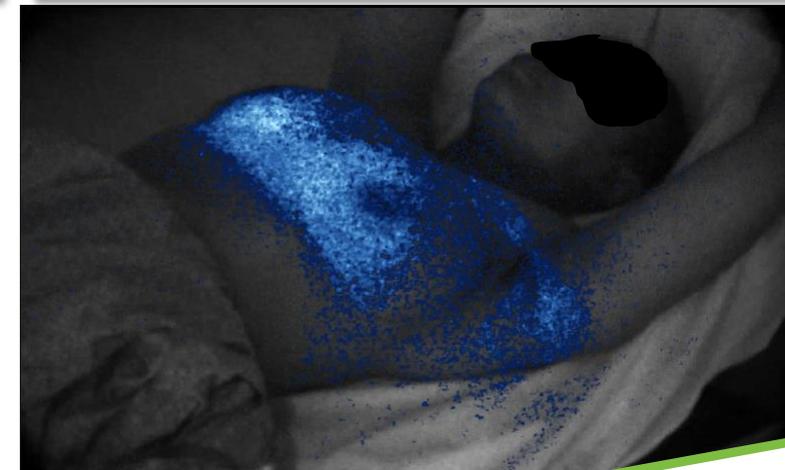


\*Alexander et al. Retrospective Evaluation of an Always-on Cherenkov Imaging System for Radiotherapy Quality Improvement. Medical Physics Oct. 14 2023. <https://arxiv.org/abs/2110.07494>

# QUALITY AND SAFETY: IMPROPER PORT TECHNIQUE

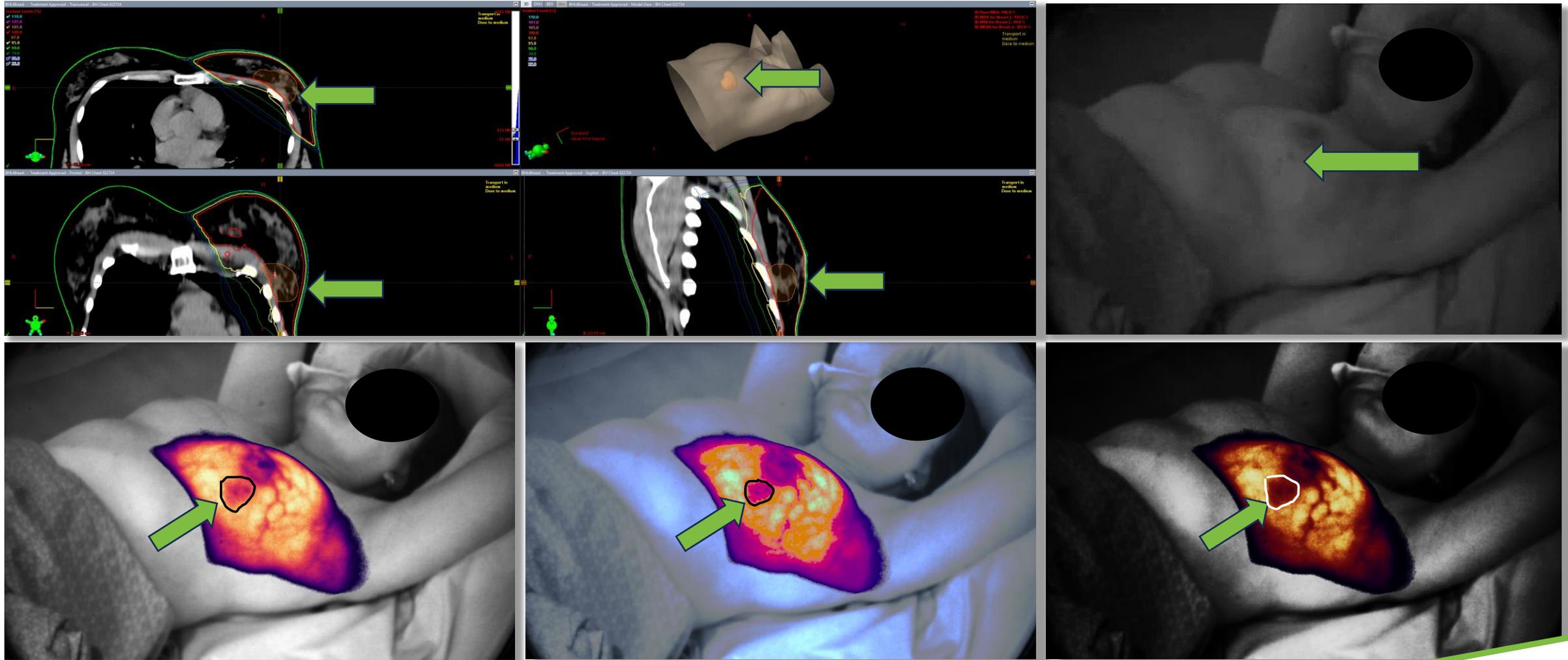


- 36 Year Old Female undergoing DIBH for left intact breast treatment
- Intended 3D surface dose rendering provided to treatment staff via the TPS
- Visual verification of treatment dose initiated from first day of treatment
- Identification of stray anomalous dose witnessed during video review of Fx1
- Incorrect port film technique found to have been assigned by staff
- Corrected for Fx2 and beyond



# CASE STUDY: TARGET COVERAGE VISUALIZATION

\* Resection Cavity: Visualization and Evaluation of Breast Target Changes...



- Potential evaluation of large seroma changes for replanning
- Cone down boost targeting

# CASE STUDY: FIELD ALIGNMENT

Visualization of CSI Field Junctions After Treatment Delivery...

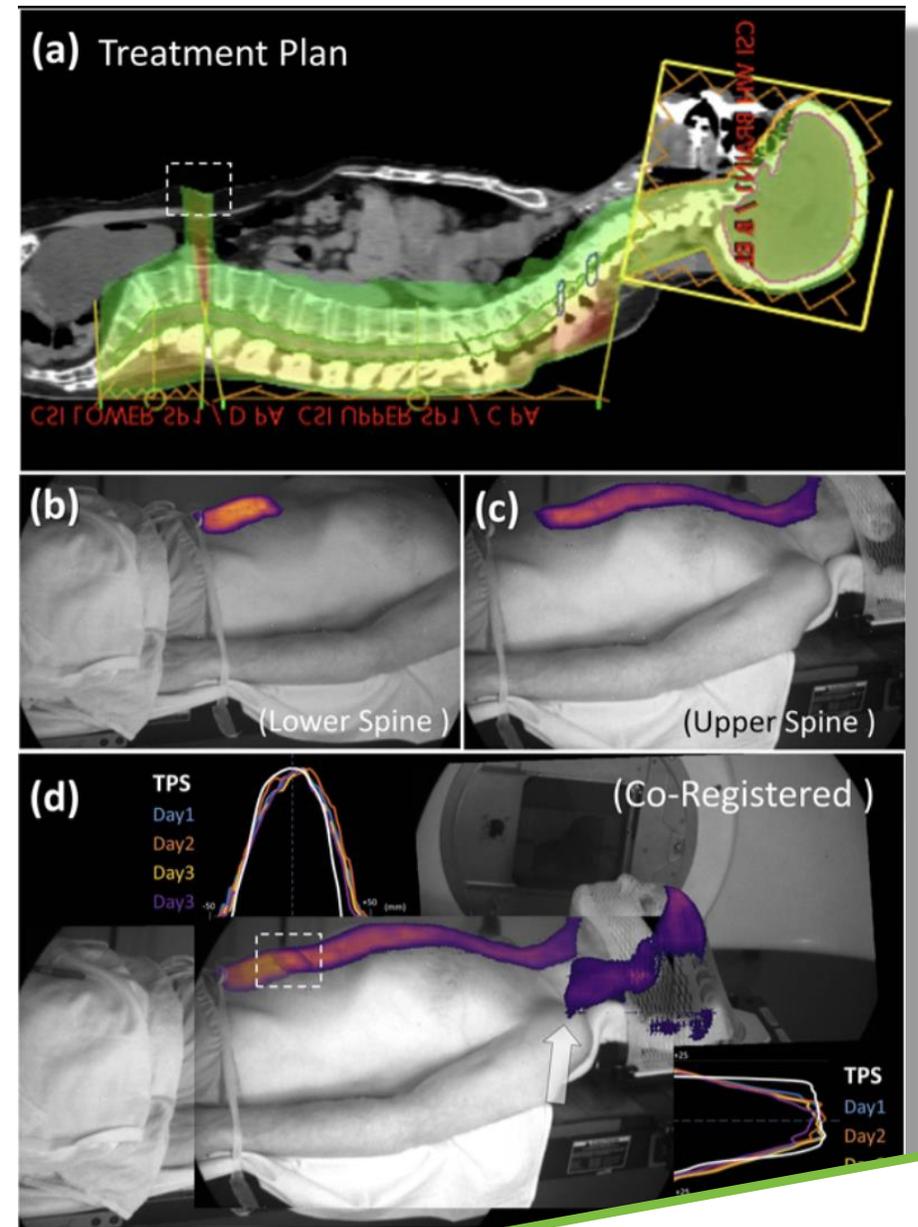
A treatment plan for cerebral-spinal irradiation (CSI) is shown

- which was characterized by four fields and three isocenters: a right and left lateral whole brain field, an upper spine field and a lower spine field. A technique for stitching together the

Cherenkov treatment images was developed by first

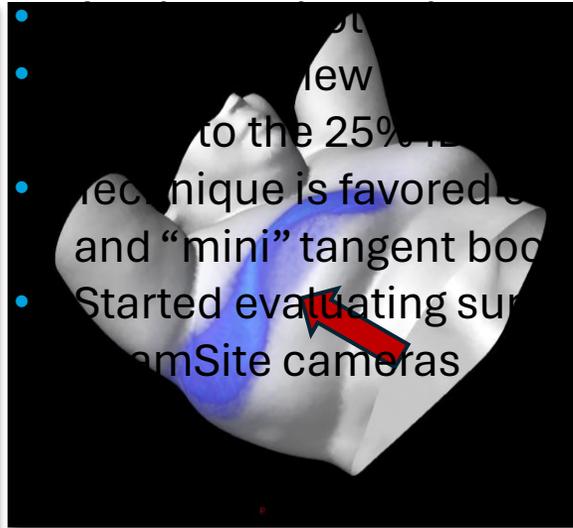
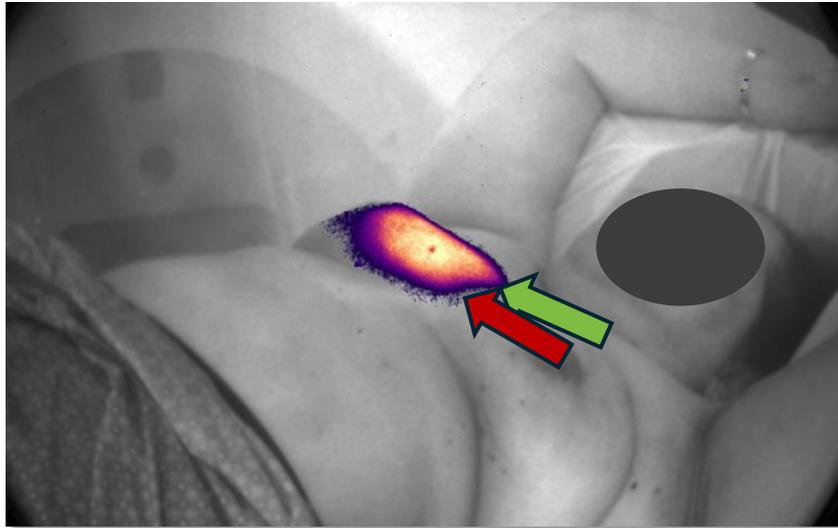
- isolating the lower spine field individually
- isolating the upper spine
- Image shows profiles comparing days 1 through 4 of lower and upper spine junction areas, as compared what was seen in the treatment plan.

Jarvis LA et al. Initial Clinical Experience of Cherenkov Imaging in External Beam Radiation Therapy Identifies Opportunities to Improve Treatment Delivery. *Int J Radiat Oncol Biol Phys.* 2021 Apr 1;109(5):1627-1637

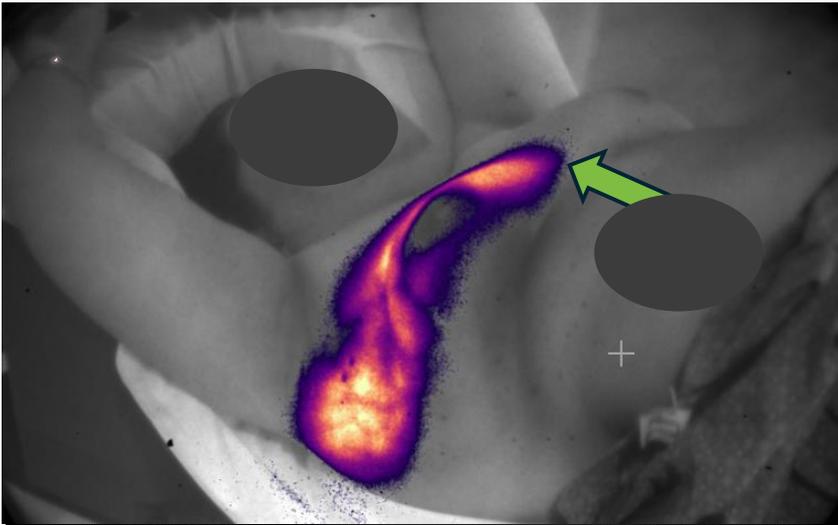
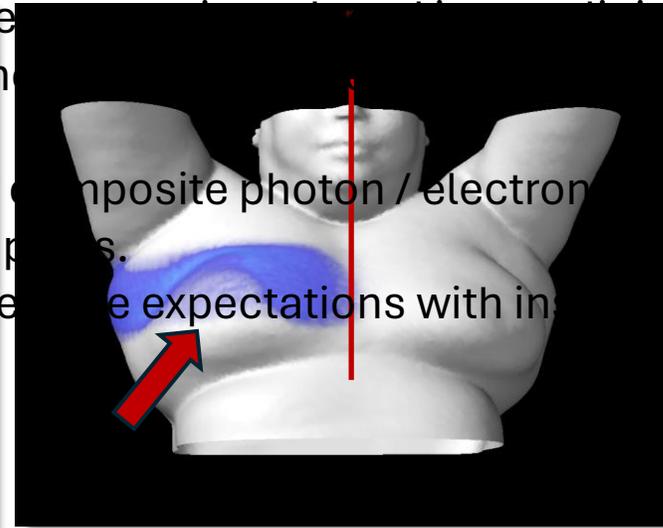


# CASE STUDY: NEW DISCOVERIES IN PLAN EVALUATION

New Plan Evaluation Methods Highlight Missing Information: Seeing What They Don't Show You...

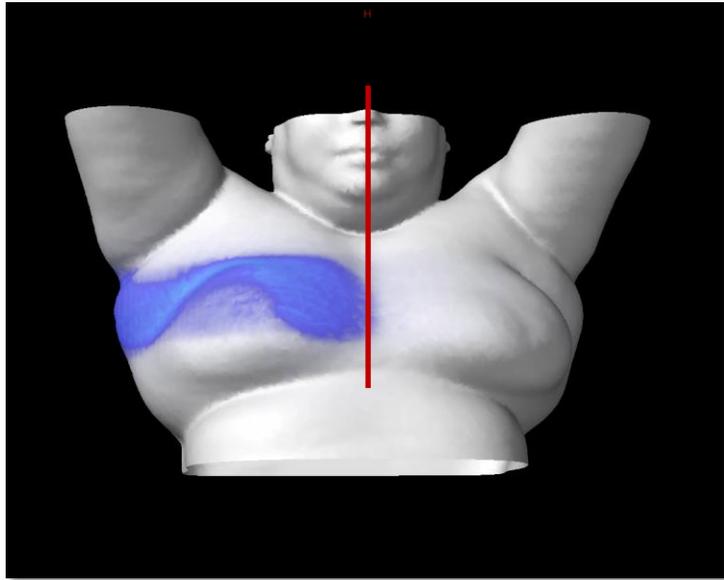


- 
- new
- to the 25%
- technique is favored
- and "mini" tangent bo
- Started evaluating sur
- amSite cameras

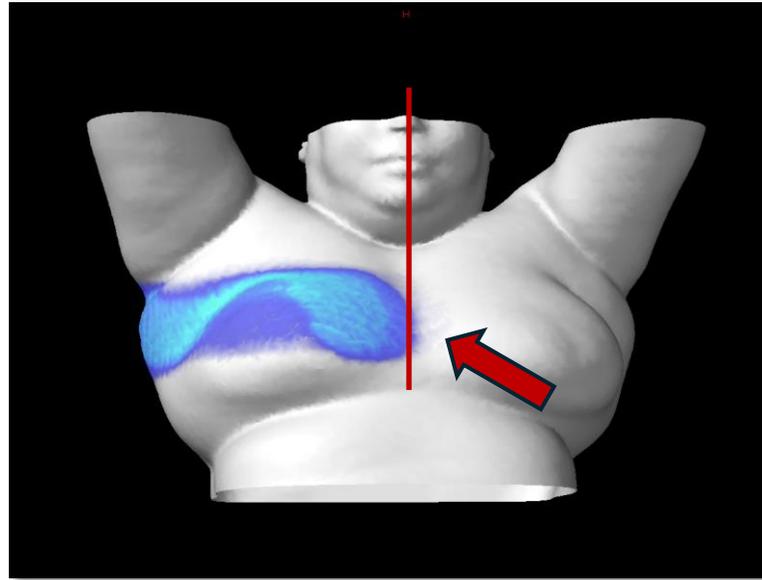


# CASE STUDY: NEW DISCOVERIES IN PLAN EVALUATION

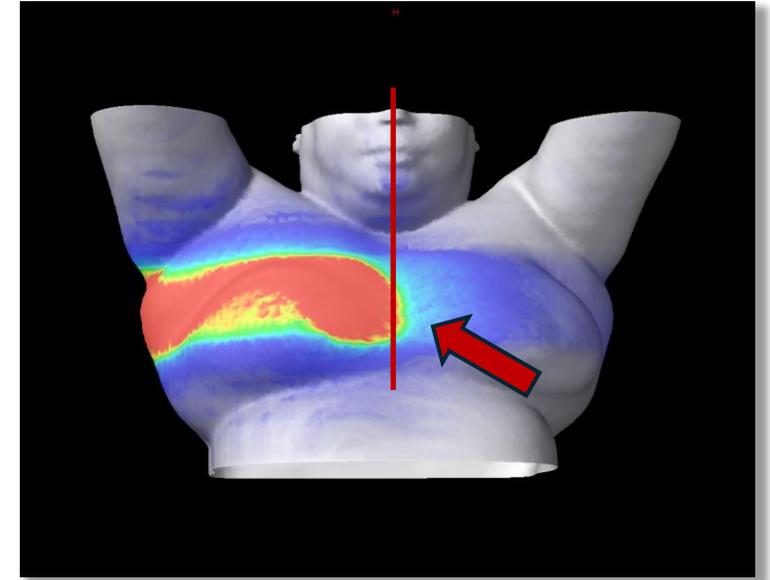
New Plan Evaluation Methods Highlight Missing Information: Seeing What They Don't Show You...



Max 1000cGy, Min 1cGy



Max 500cGy, Min 1cGy

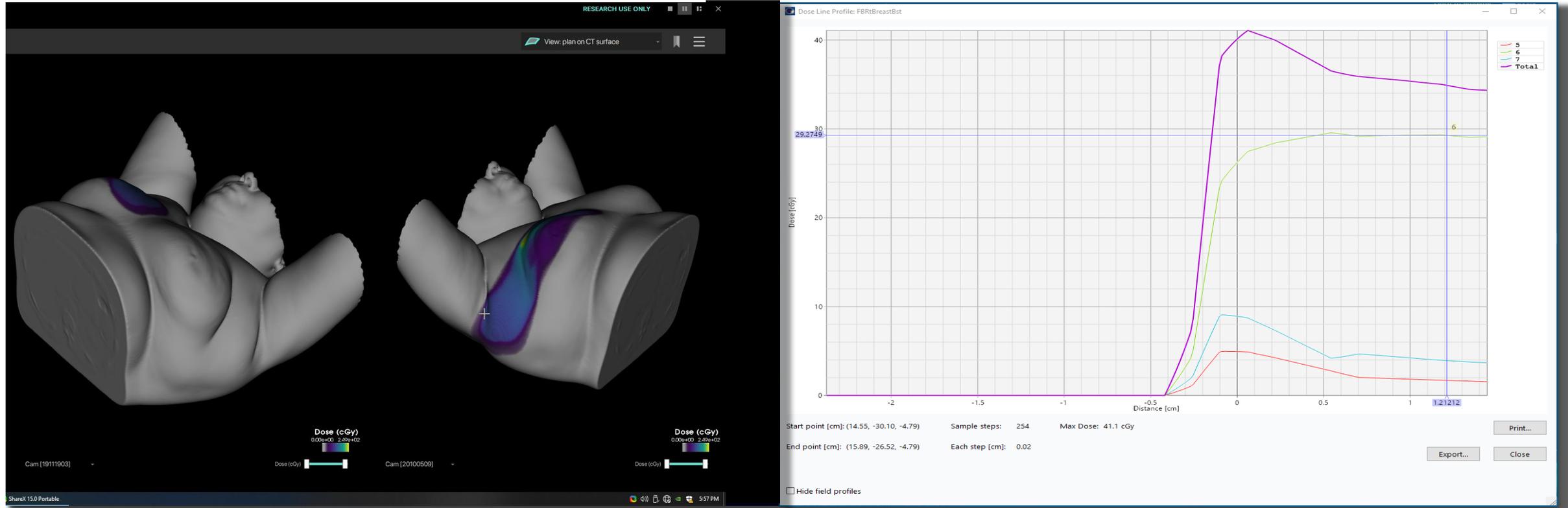


Max 100cGy, Min 1cGy

- Fixed binning of the dose for surface dose visualization results in “**less than representative**” display.
- Adjusting the max dose within Eclipse appears to adjust the width of a fixed number of dose bins (or levels).
  - This effectively “hides” lower doses if the width of those bins becomes too large
- Lower doses were not visualized effectively until the Max dose dropped to approx. 10% of the Rx dose
  - Need a more representative way of displaying the surface dose expectation during treatment
- **Cherekov imaging was effective in visualizing these lower doses.**

# CASE STUDY: NEW DISCOVERIES IN PLAN EVALUATION

New Plan Evaluation Methods Highlight Missing Information: Seeing What They Don't Show You...



- Taking a profile through the region where the dose is seen in the treatment imaging shows an approx. 4-5% IDL
  - Majority of the dose in this region is contributed by the exit dose from the arc field
- **A tool that more accurately predicts the surface dose and its visualization could be used to evaluate plans before approval and delineate a region of expected dose during treatment.**

# SUMMARY

- We are still learning all the potential applications of this new and exciting technology
- Cherenkov imaging shows promise in revealing previously unidentifiable treatment related issues
- Cherenkov imaging has already allowed us to
  - Improve treatment safety by providing real-time visual feedback of dose delivery to the care team.
  - Identify and monitor potential stray radiation during treatment and take rapid corrective action.
  - Confirm patient compliance during treatment.
  - Track patients with unusual body habitus and / or physical limitations.
  - Identify, track, and correct planning errors, near misses, and suboptimal treatment processes faster and more effectively than traditional methods allow.
- Cherenkov imaging continues to change the way we review plan quality
- Cherenkov imaging shows the potential to have unique applications throughout all aspects our quality management program.



**Thank You.**  
**Any Questions?**