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Using Cherenkov Imaging and Scintillation Dosimetry to Quantify Contralateral Breast Dose in Breast Radiotherapy Treatments: The EDUCATE Trial

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Using Cherenkov Imaging and *in vivo* Dosimetry to Quantify Contralateral Breast Dose in Breast Radiotherapy Treatments

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Disclosures

- This work was conducted using a research system, so some of these features are unique to the version used at Dartmouth-Hitchcock
- This work was partially funded by the following research grants:
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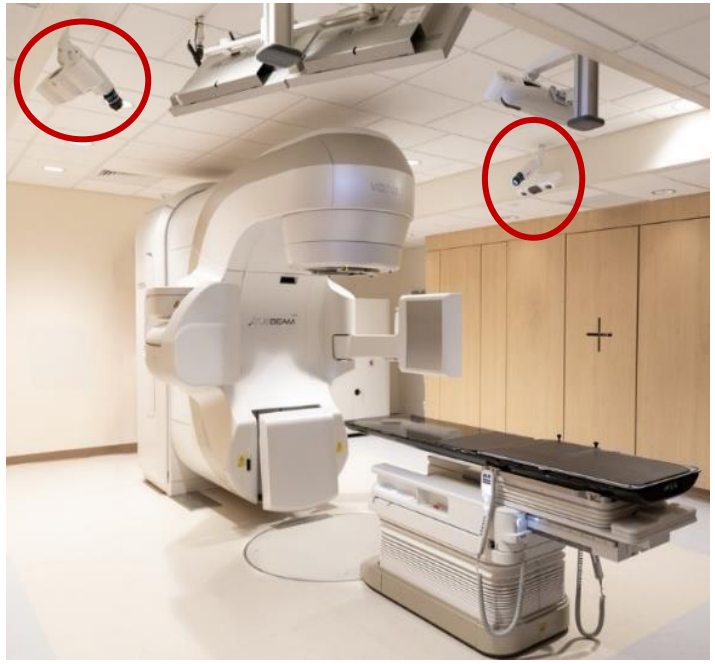
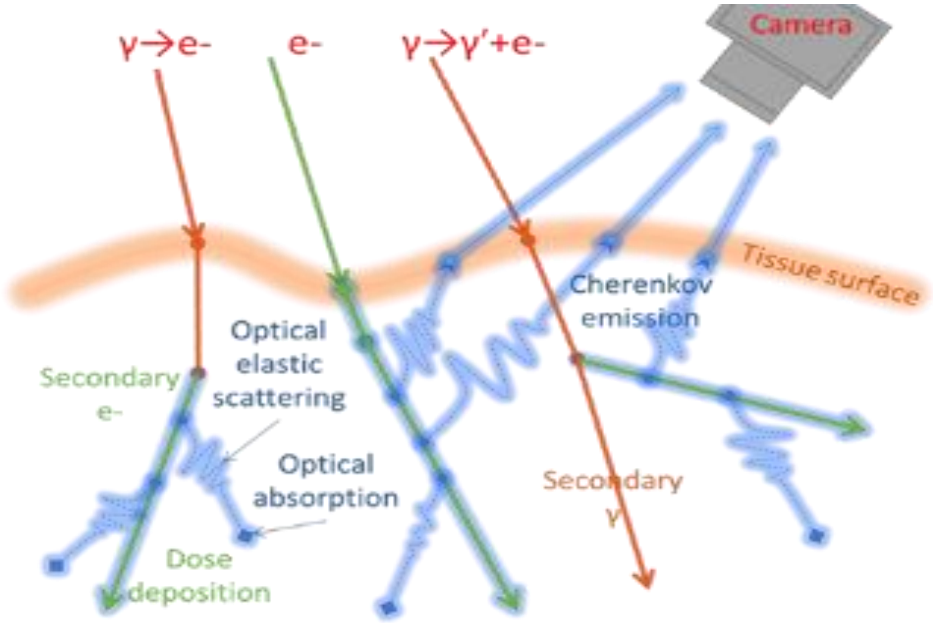
  - Dartmouth Cancer Center CORE grant P30CA023108
- Travel award to attend this meeting was provided by the SGRT community
- There are members of the research team that have a financial interest in DoseOptics

Objectives

1. Introduction to clinical Cherenkov imaging
2. Evaluating breast RT with Cherenkov imaging on the EDUCATE Trial
3. Conclusions

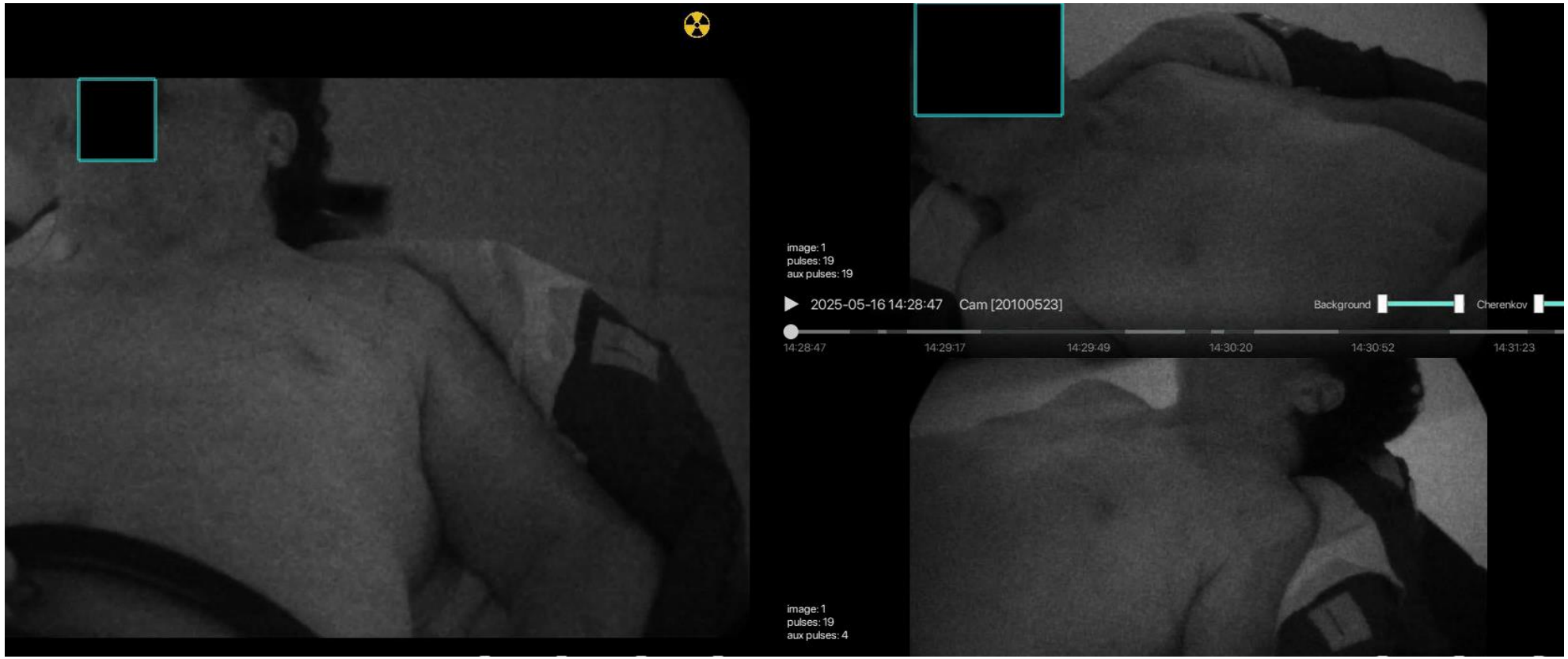
Cherenkov imaging is a methodology that allows for visualization of radiotherapy beams on patients





What types of images are created?

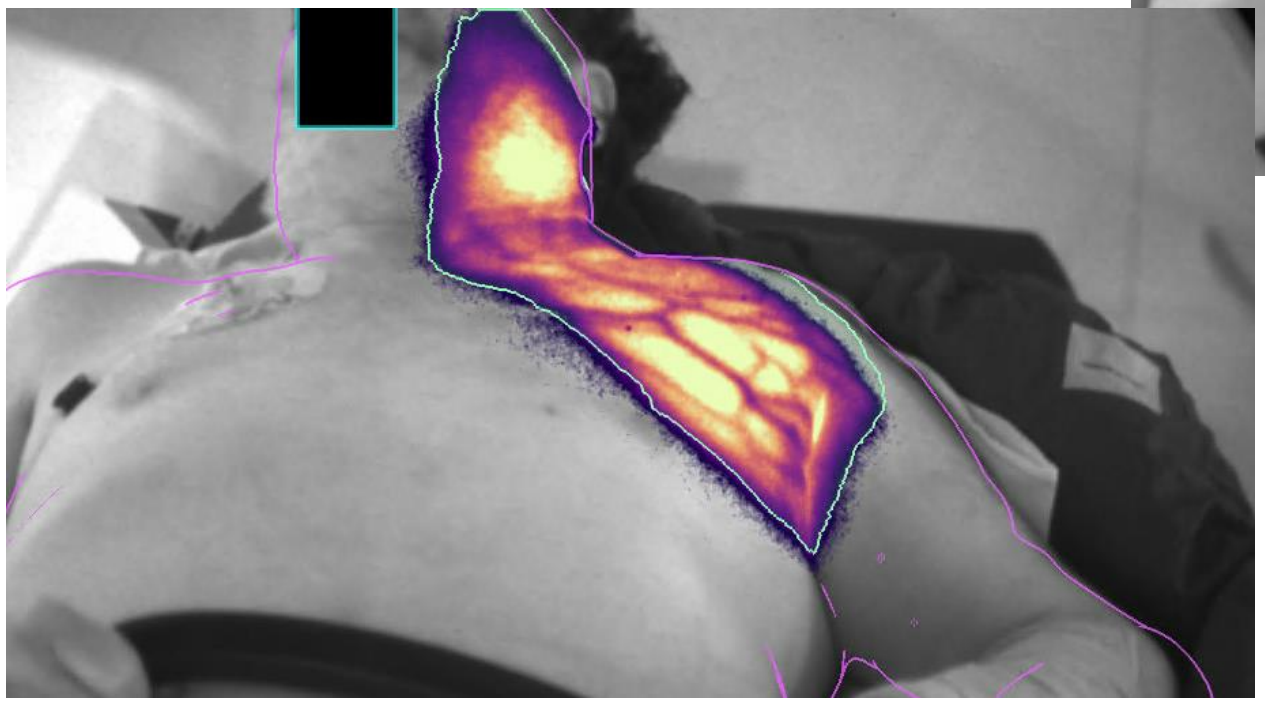
Real-time viewing and offline video viewing



What types of images are created?

Cumulative images

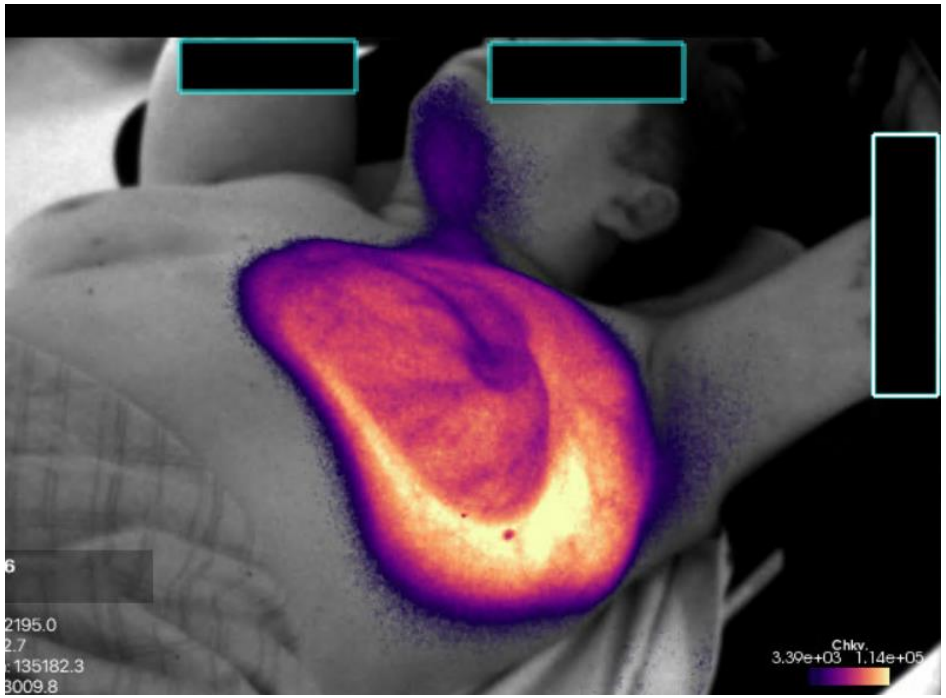
How does the image I see compare with the planned treatment?



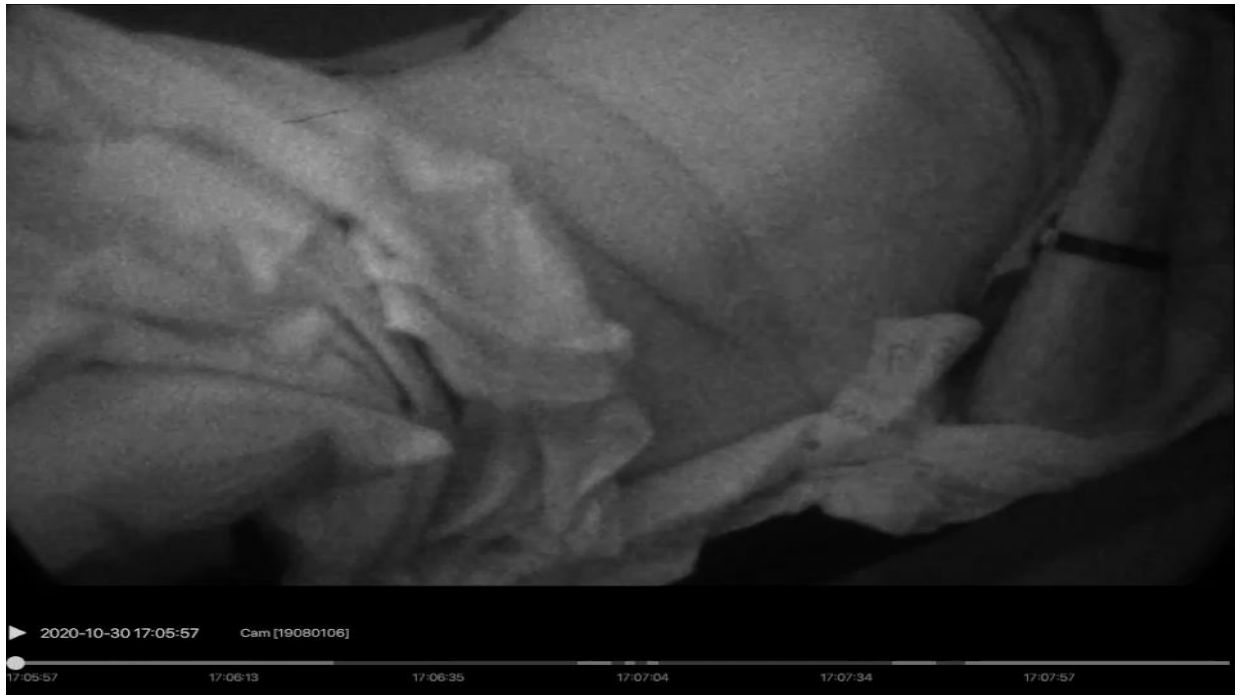
TPS-derived plan overlay (green) allows comparison of the delivered and planned treatments – Research version feature

In addition to confirming accurate treatment delivery, Cherenkov imaging detects when unintended sites are exposed to radiation

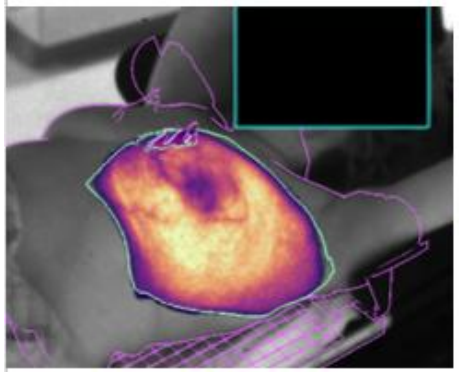
Dose extending to chin



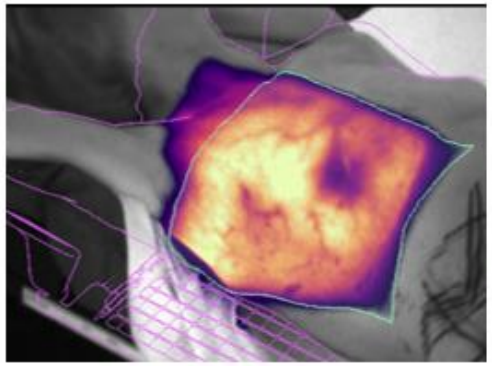
Patient moving arm into treatment field



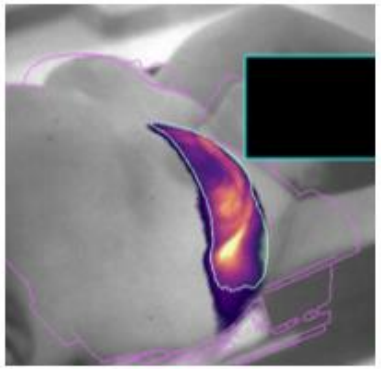
Visualizing breast treatments



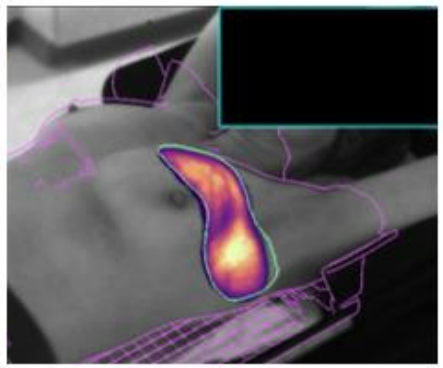
Whole Breast with Tangents



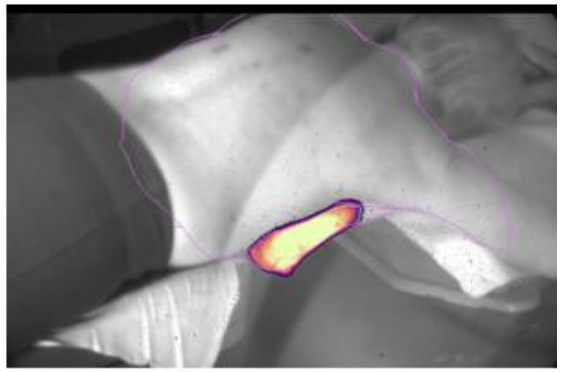
Whole Breast Tangents + RNI



Accelerated Partial Breast Irradiation (aPBI) with VMAT

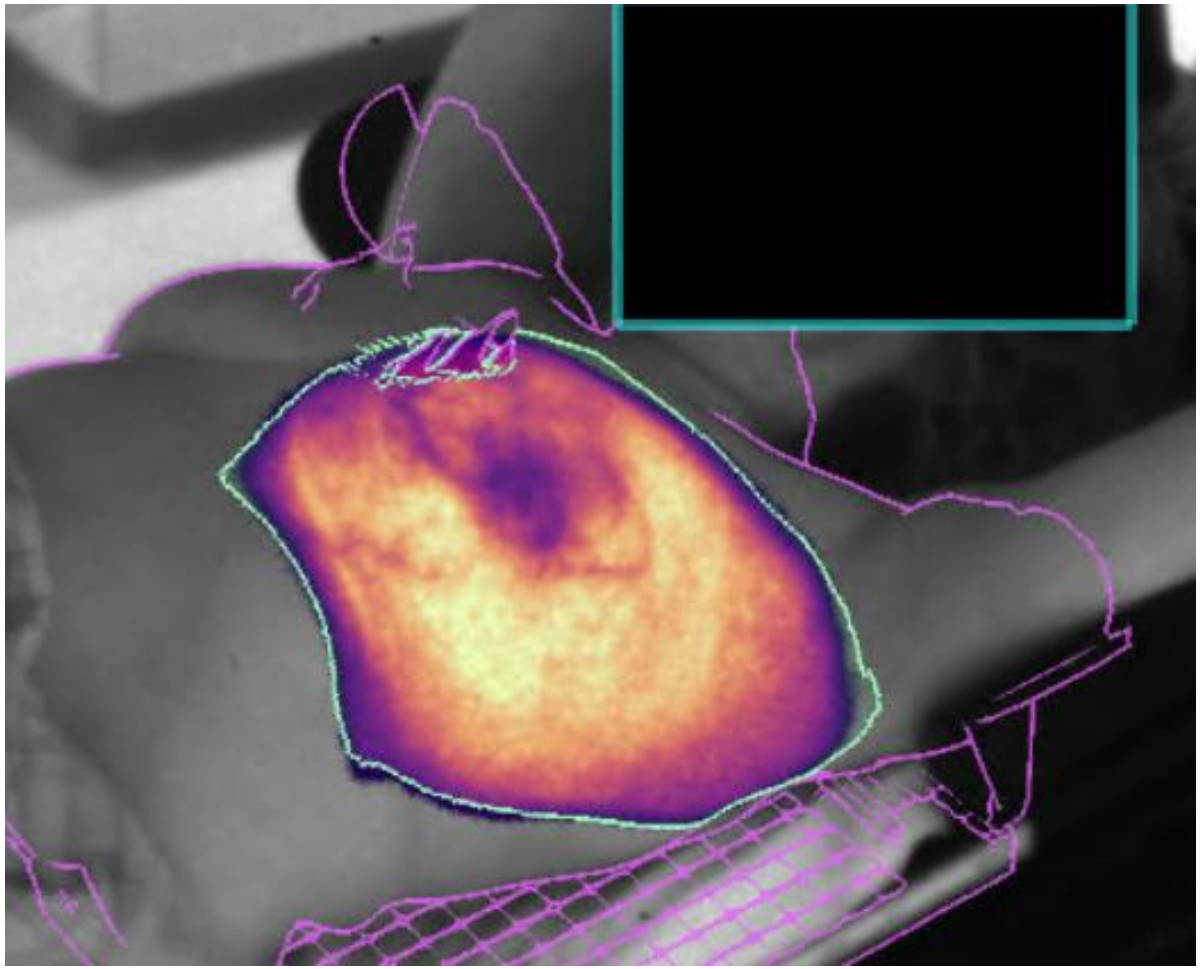


Partial Breast "Mini Tangents"

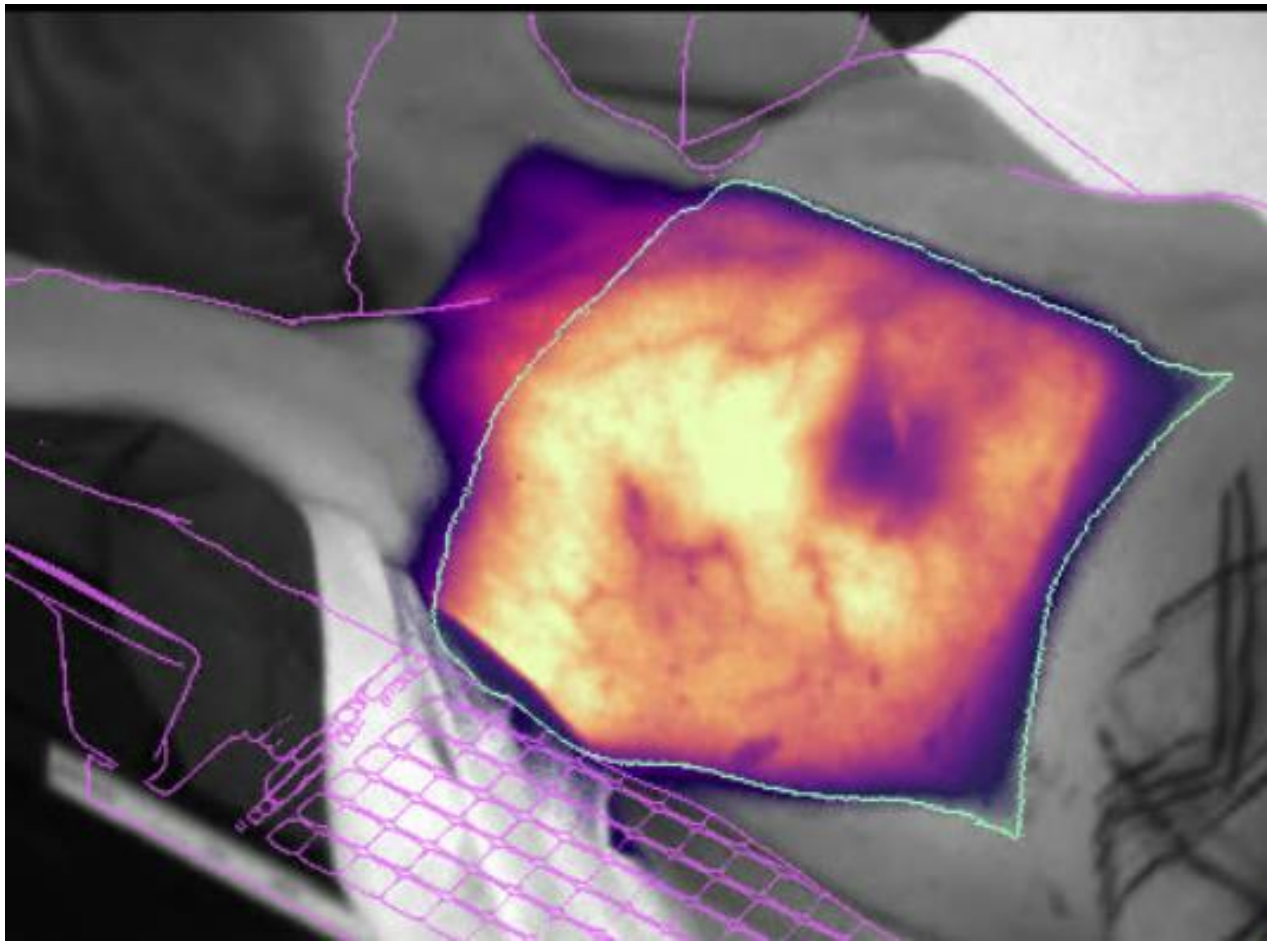


Prone Tangents

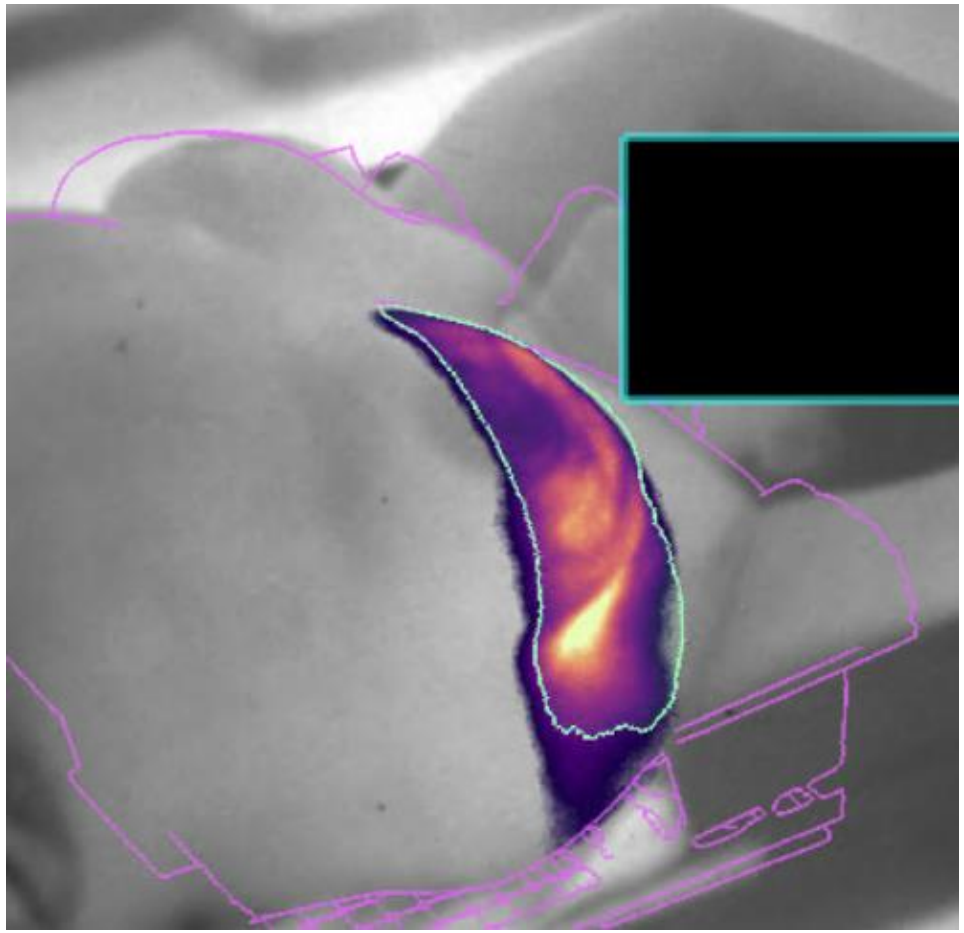
Whole Breast with Tangents



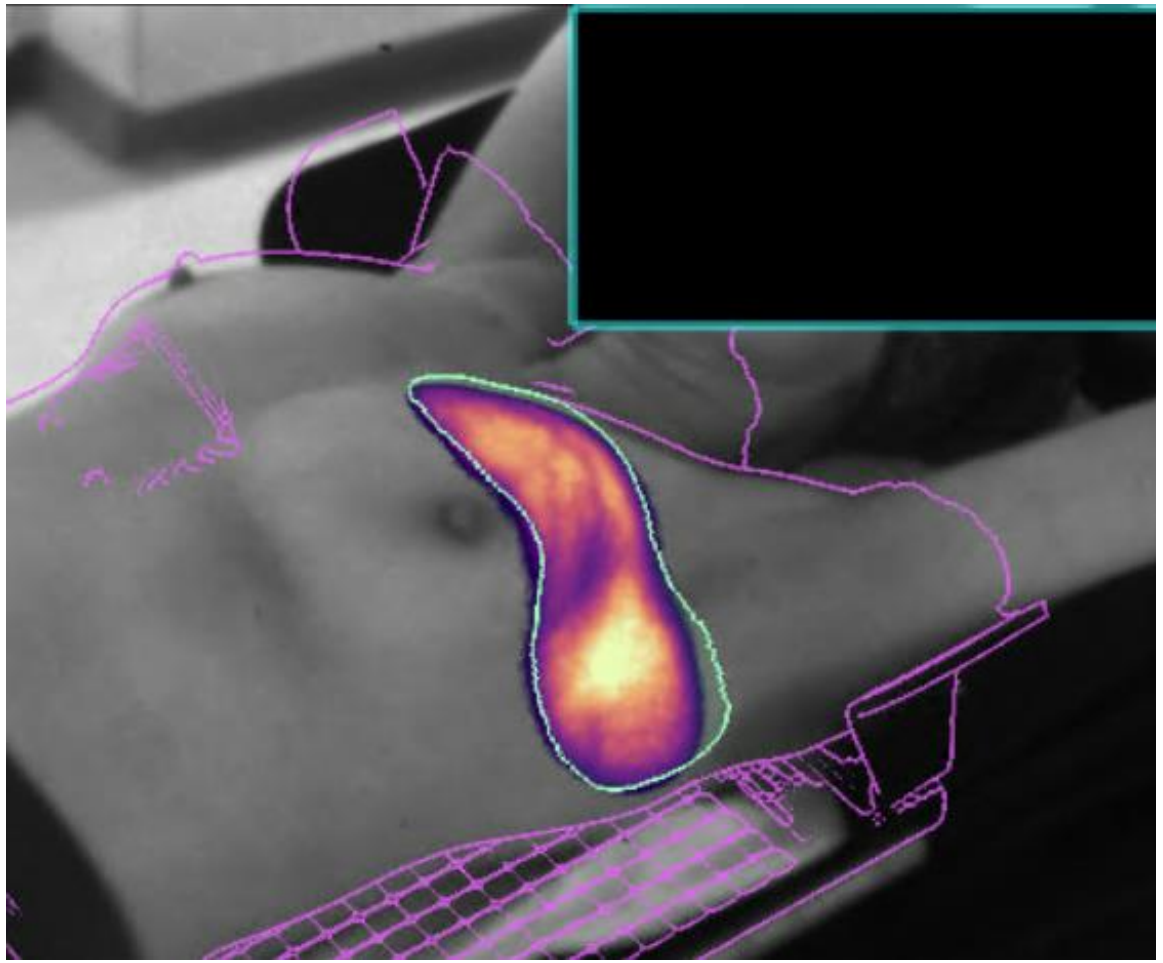
Whole Breast Tangents + RNI



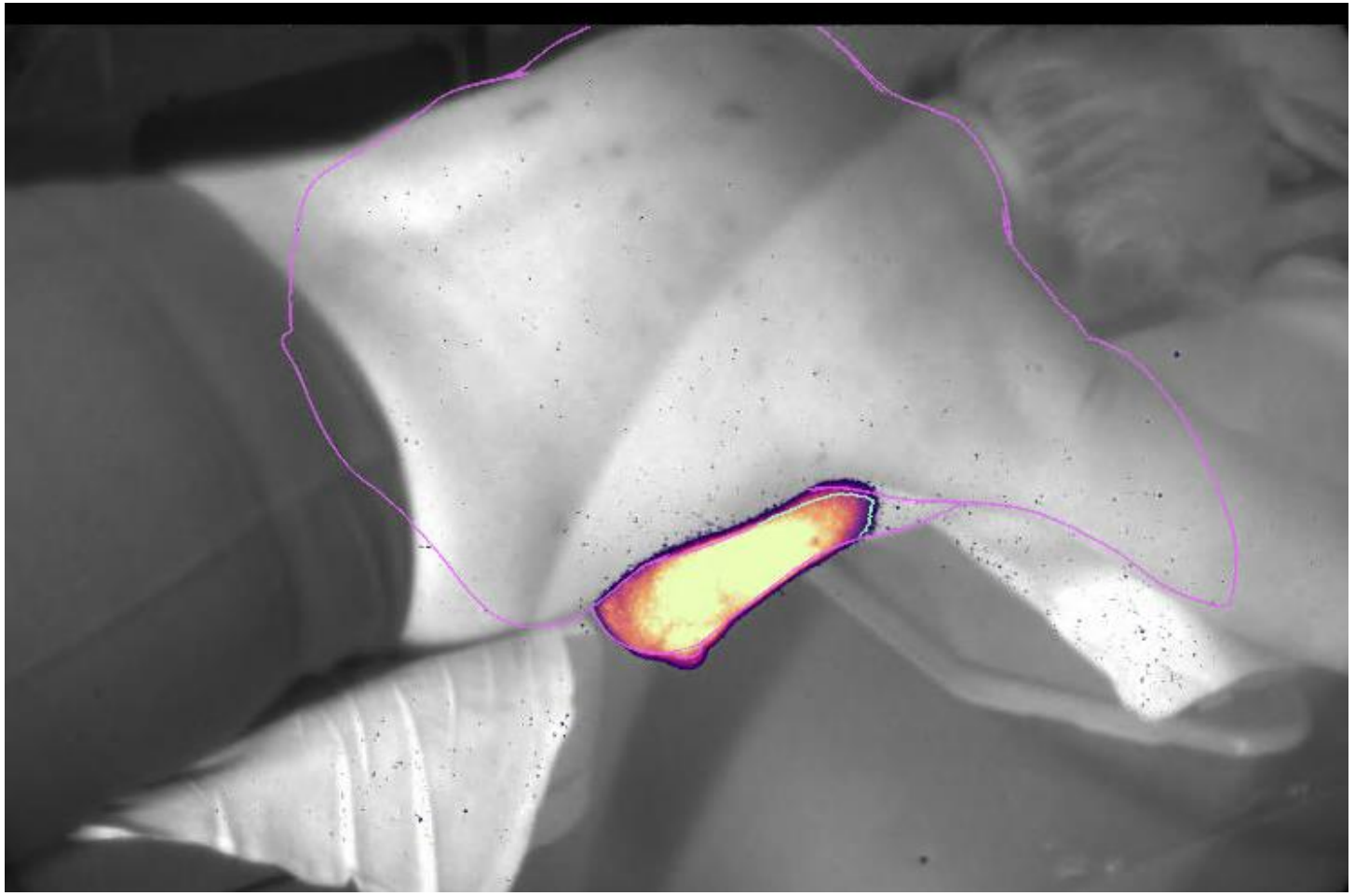
Accelerated partial breast irradiation (aPBI) with VMAT



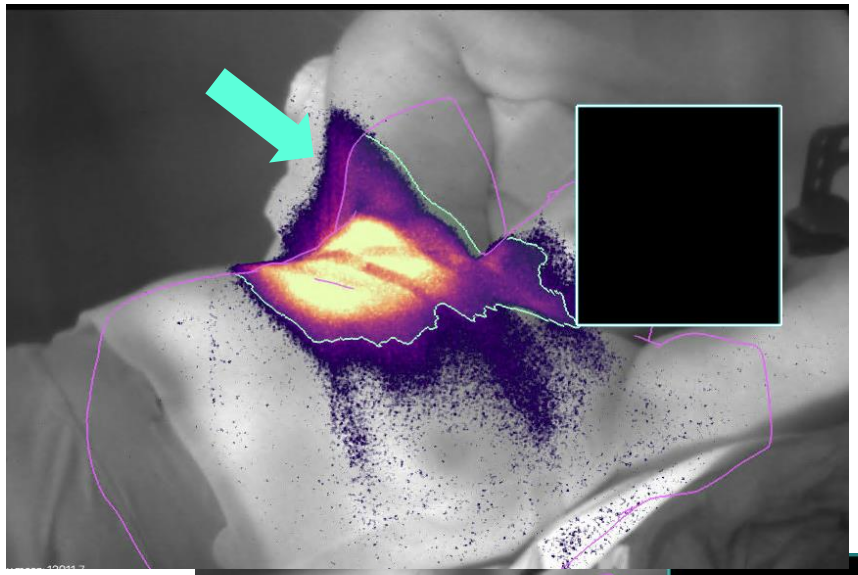
Partial Breast “Mini Tangents”

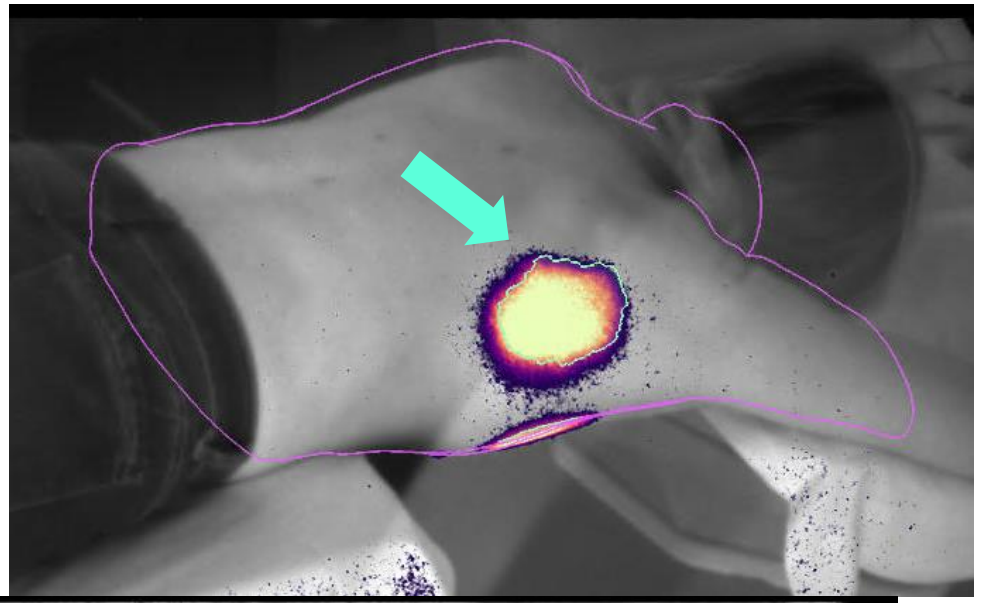


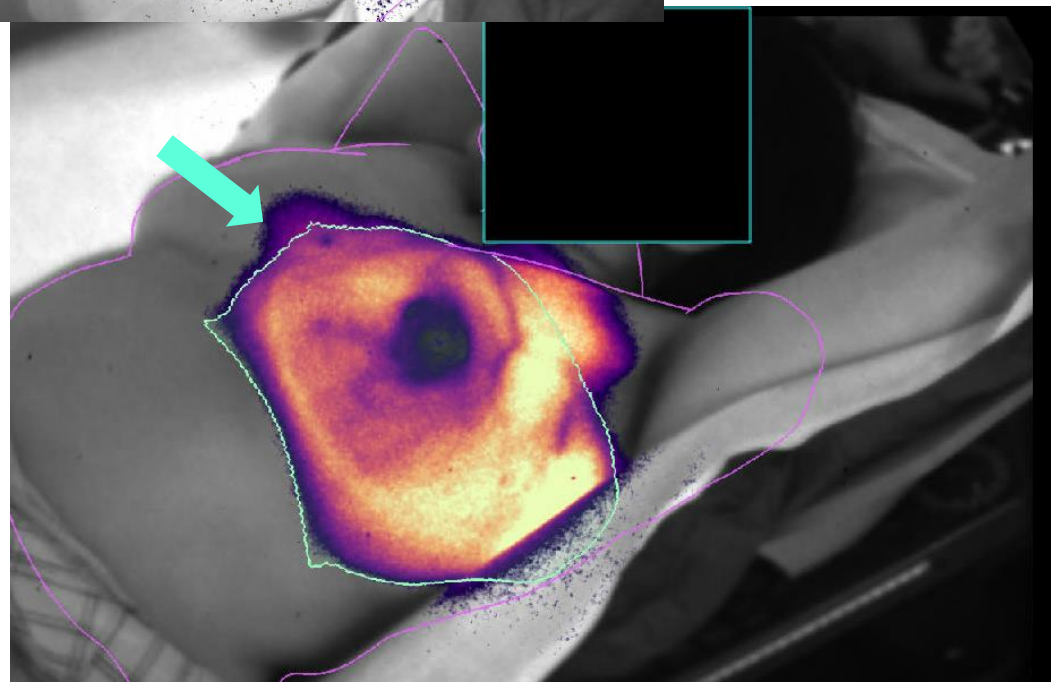
Prone Tangents

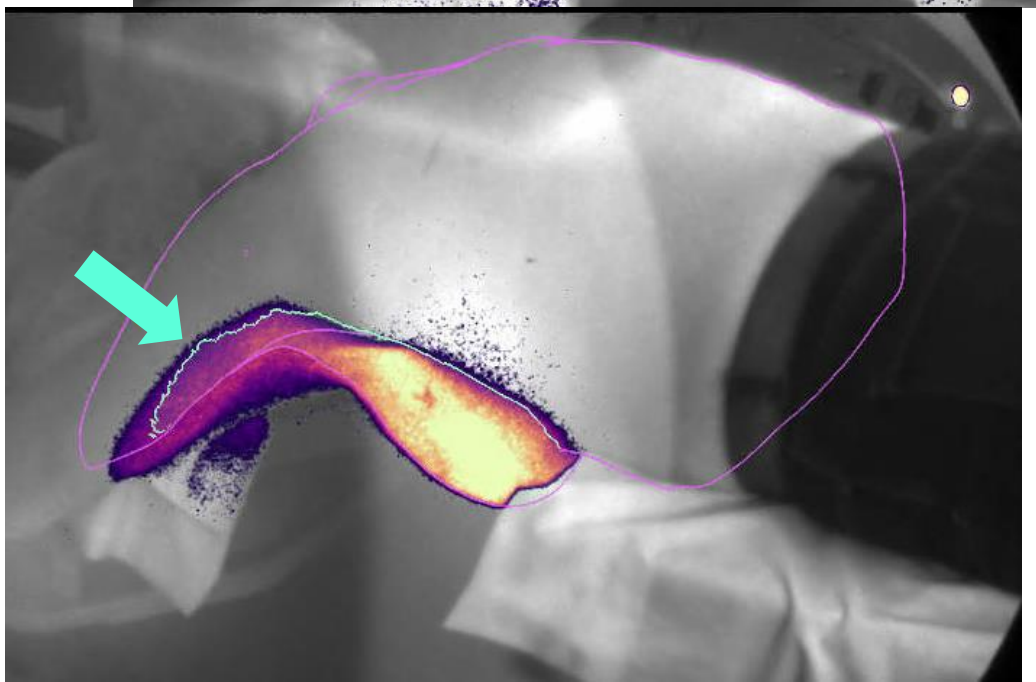


Cherenkov images reveal “misplaced” dose during breast treatments

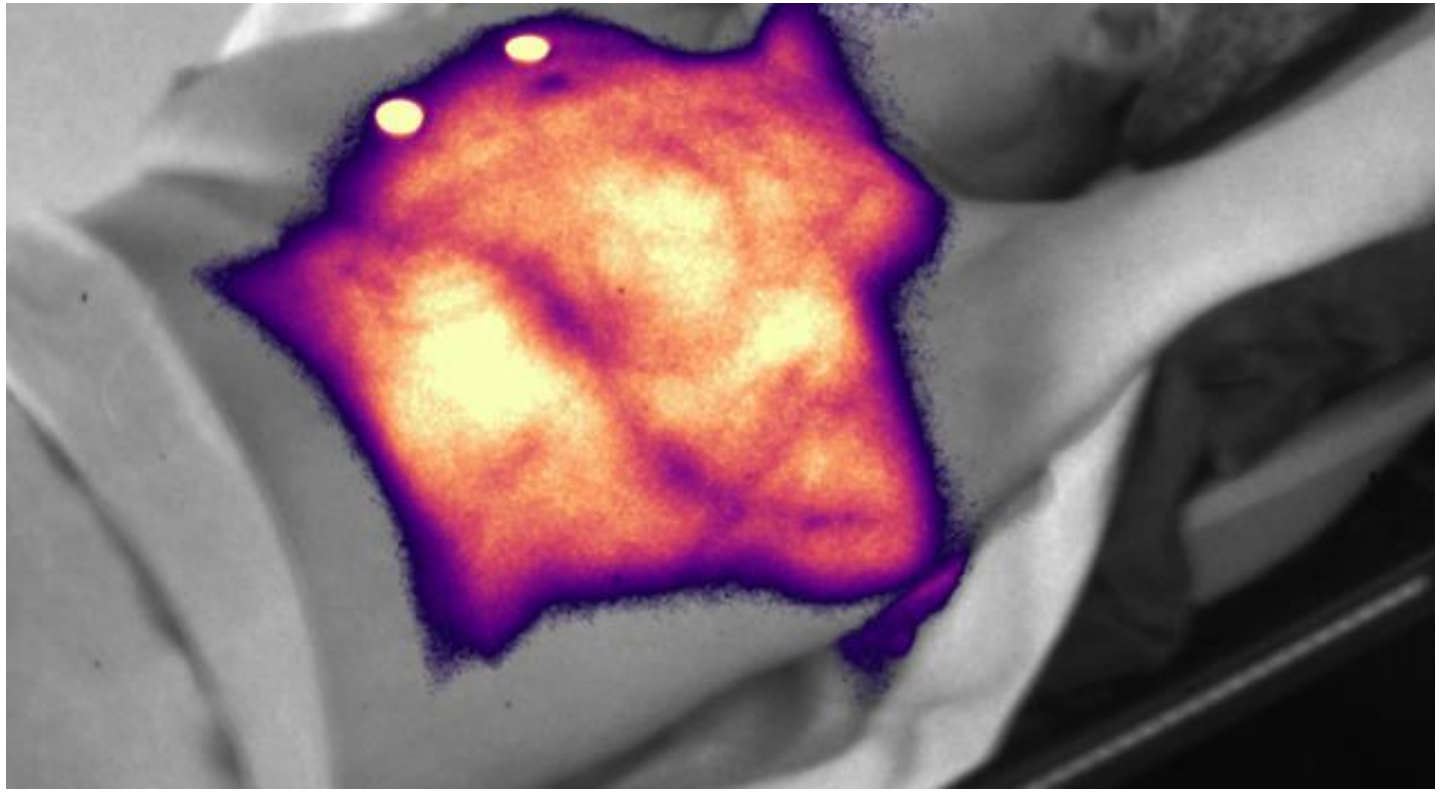


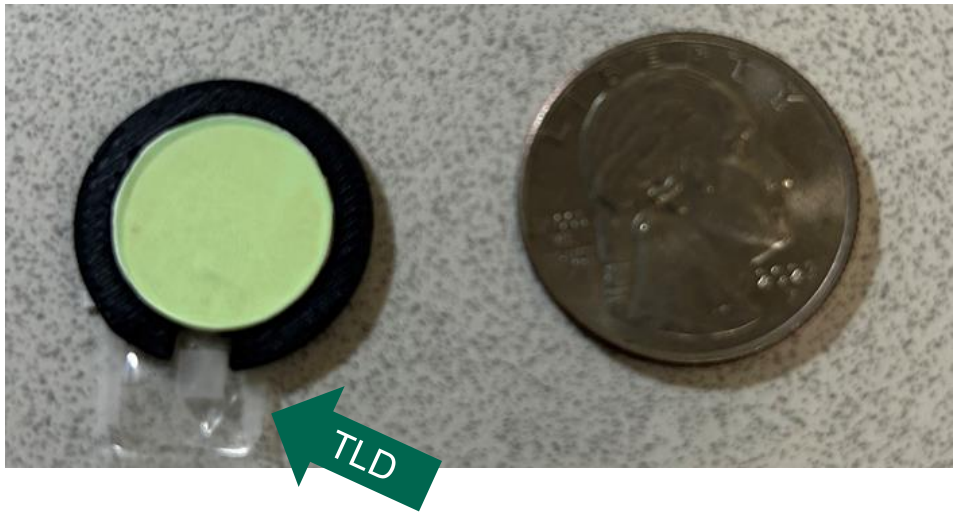




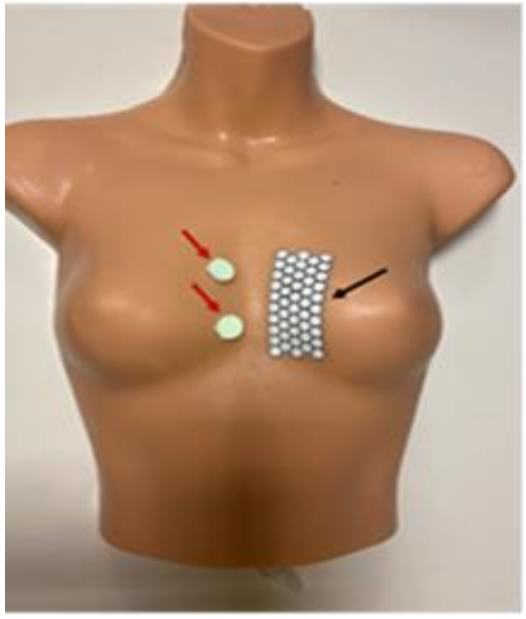


When combined with *in vivo* dosimetry, visualized dose can be quantified





Scintillating disc (DoseDot) in plastic holder



Scintillator discs and mesh on phantom

Evaluating ***D***ose ***U***sing ***C***herenkov ***A***nd scintillation ***TE***chnolgy

The EDUCATE trial

Limiting contralateral breast dose (CBD) is a critical goal in the planning & delivery of breast RT

- Why do **WECARE**? CBD in excess of 1 Gy in young patients is associated with elevated risk of a subsequent contralateral breast cancer
  - Dose constraint of Dmax $\leq$ 2 Gy may be accepted for older patients
- Since the WECARE data have been published, we've seen some changes in breast RT
  - Expanded indications for irradiation of the IMNs
  - Adoption of VMAT techniques
- Plus, Cherenkov imaging has shown us that there are times where CBD is present, but we just can't detect or appreciate the magnitude using standard methods

Hypothesis: Incidence of CBD in modern clinical practice may be underappreciated

Stovall et al., *IJROBP.* 2008.

EDUCATE objectives

1. To establish the incidence of CBD in routine clinical practice
2. To quantify CBD using Cherenkov-image-guided *in vivo* dosimetry
3. To determine the root causes of CBD
   - Distinguish between planned vs unplanned CBD
   - Minimize CBD in future treatments, when possible

METHODS

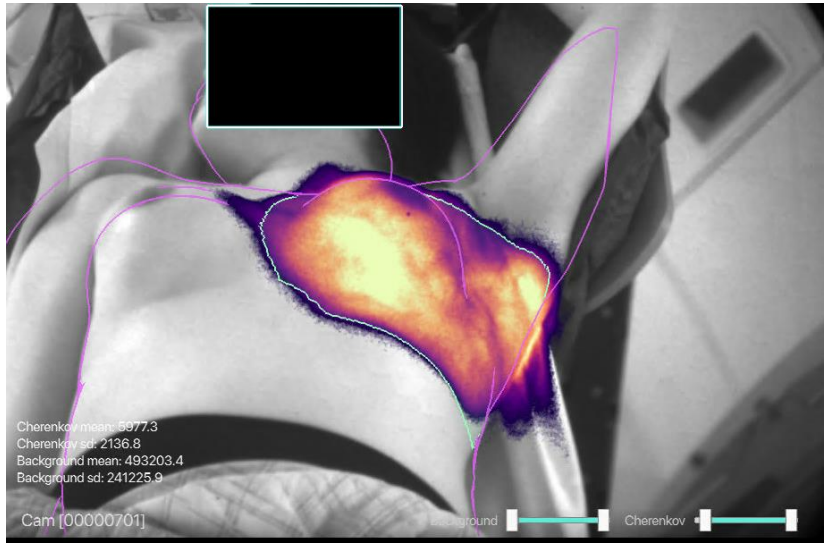
- Daily Cherenkov image review of all breast treatments at an academic & community medical center to identify CBD
- Measure CBD with *in vivo* dosimetry when identified

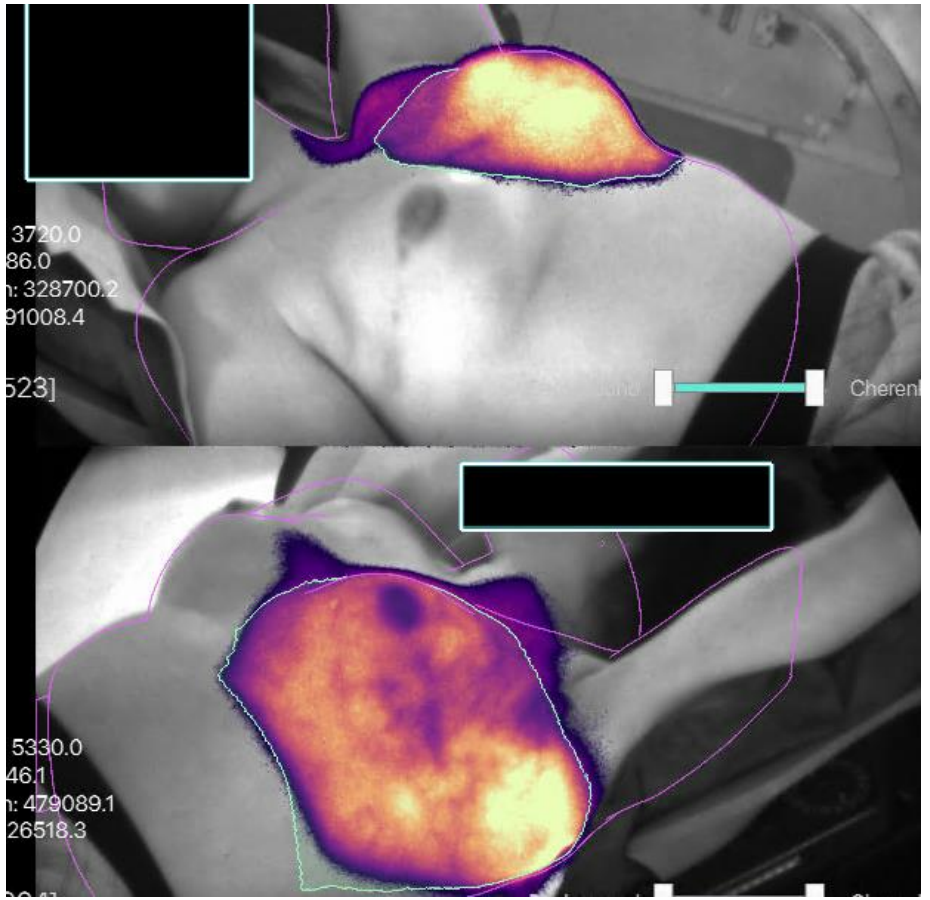
Over 40% of breast treatments show CBD on Cherenkov imaging!

- Images for **129 unique patients** over 1854 fractions reviewed over 6 months
  - **94 patients (1305 fractions) treated with supine techniques**
- CBD was identified during treatment delivery for **43%** (N = 40) unique patients!

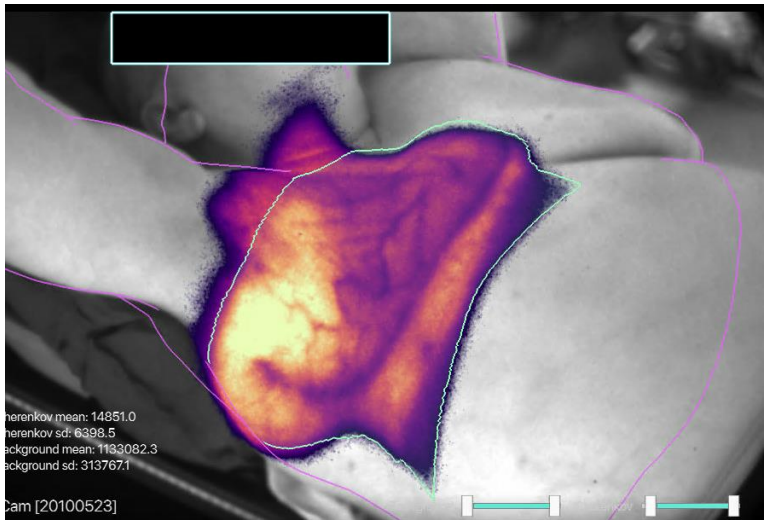
Rates of CBD vary by technique

- Tangents **11%** (6/56)
- Wide tangents **93%** (13/14)
- Tangents with medial electrons **100%** (2/2)
- aPBI with VMAT **100%** (17/17)
- Chest wall with VMAT **100%** (2/2)

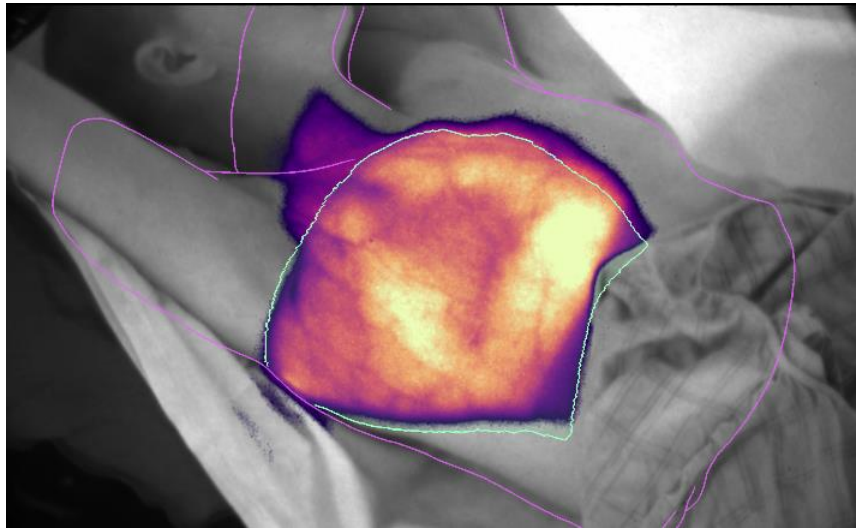




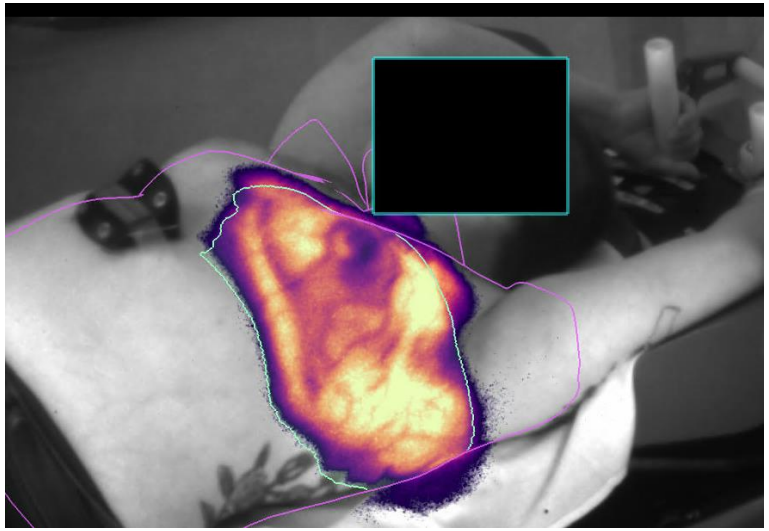
CBD was unplanned in 10% of cases!



Planned CBD



Unplanned CBD



Combination of planned & unplanned CBD

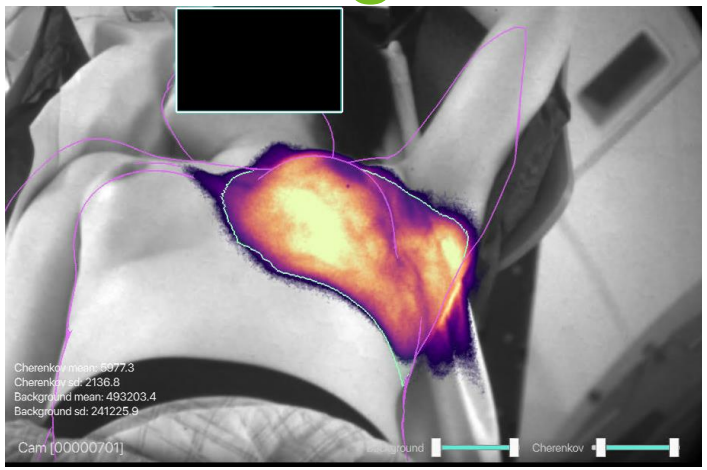
Measured dose to contralateral breast exceeds dose constraints for 3D treatments

	Wide Tangents 7 patients	Tangents + Medial Electrons 1 patient	aPBI with VMAT 15 patients
TLD measured dose (Gy) to CB over 1 fraction	0.256 – 2.16	1.71 – 1.94	0.07 – 0.63
Total dose (Gy) to CB if summed across all fractions	6.38 - 34.5	42.8 - 48.5	0.35 – 3.15
Number of treatment courses that have CBD in excess of the 2 Gy dose constraint	100%	100%	7%

*CB = contralateral breast

CB dose constraint: Dmax $\leq$ 2 Gy

17% (22) of patients in this cohort are age 50 or younger!



- Of these patients, **27%** (6/22) had **CBD** on imaging
- 2 of these patients underwent dose measurement

Patients under 50 had CBD in excess of this dose constraint!

- Future work includes monitoring every young patient with Cherenkov imaging to eliminate unplanned dose

Goal: Reduce the 10% rate of unplanned CBD to 0%!

Conclusions

- **Cherenkov imaging is an excellent tool for confirming delivered dose and finding extraneous dose, such as CBD, during breast treatments**
- **Cherenkov imaging combined with *in vivo* dosimetry can optimize dose evaluation at key sites, such as the contralateral breast**
- **CBD causes vary, and at times Cherenkov imaging can lead to improved treatments that minimize extraneous dose**
- **CBD and may be under-appreciated**
- **Because cases of early onset cancers are rising, understanding causes and risks of CBD are more important than ever**

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Thank you

Acknowledgments:

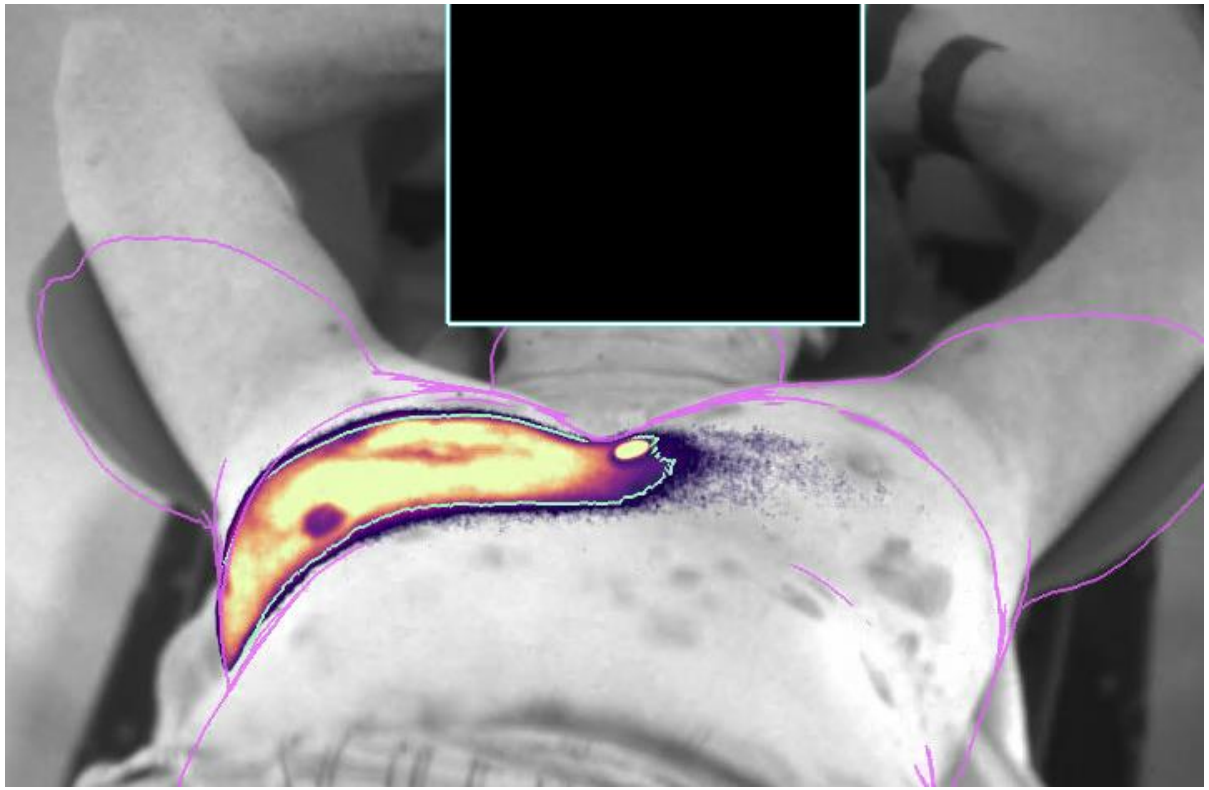
- This work would not be possible without the Cherenkov research group and the support of our excellent and very accommodating RTTs
- Thanks to our study coordinators who keep things running
- ***Special thanks to all the patients*** would participated in the dose measurement portion of this study

References

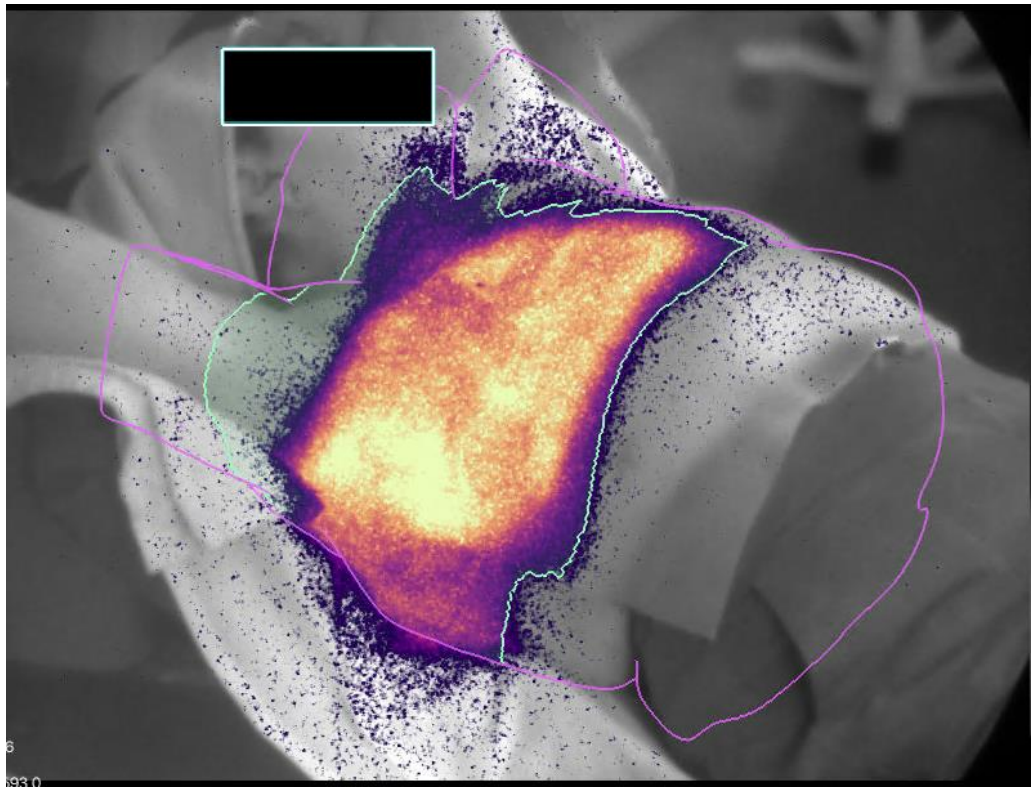
Watt GP, Smith SA, Howell RM, Pérez-Andújar A, Reiner AS, Cerviño L, McCormick B, Hess D, Knight JA, Malone KE, John EM, Bernstein L, Lynch CF, Mellemkjær L, Shore RE, Liang X, Woods M, Boice JD, Dauer LT, Bernstein JL. Trends in Radiation Dose to the Contralateral Breast During Breast Cancer Radiation Therapy. *Radiat Res*. 2023 Oct 1;200(4):331-339. doi: 10.1667/RADE-23-00014.1. PMID: 37590492; PMCID: PMC10684055.

VMAT cumulative images

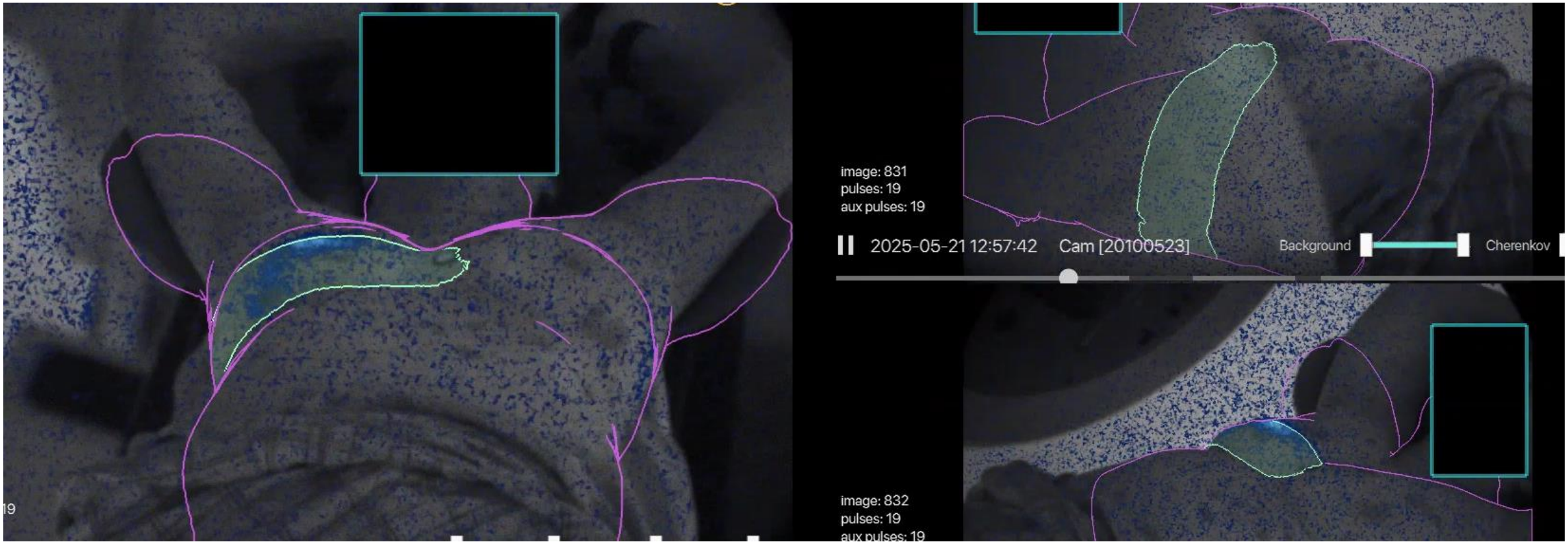
aPBI with VMAT



Chest wall + RNI with VMAT



aPBI with VMAT: Video view



CBD may be planned, unplanned, or a combination of both

	Tangents* (N = 5)	Wide Tangents (N = 13)	Tangents + Medial Electrons (N = 2)	aPBI with VMAT (N = 17)	Chest Wall with VMAT (N = 2)
Planned	1 / 6	2 / 13	2 / 2	17 / 17	2 / 2
Unplanned	3 / 6	1 / 13			
Combination	1 / 6	10 / 13			

*The extent to which CBD was planned vs unplanned is unclassified in 1 case

CBD on boost deliveries

Of these patients, 6 also had boosts with CBD

- VMAT boost (1)
- Photon scar boost (2)
- Electron scar boost (2)
- 3D cavity boost with photons (1)

An additional patient had CBD on a boost without CBD noted during the whole-breast portion of treatment

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