Quantitative Assessment of Iodine Detectability As a Function of Tissue Density, Thickness and Dose in Contrast-Enhanced Mammography

Raj Kumar Panta[1*,2], Megan K. Russ[1], Ehsan Samei[1], Jeffrey S. Nelson[1]
[1]Clinical Imaging Physics Group, Department of Radiology, Duke University Medical Center, Durham, NC, USA
[2]Department of Radiology, Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA

Introduction

Contrast-enhanced mammography (CEM) is an emerging breast imaging modality that enhances tumor detection by utilizing the energy-dependent properties of iodinated contrast agents. However, there remains a lack of quantitative methods to evaluate how imaging variables - such as tissue density, breast thickness, and dose, affect iodine detectability.

Purpose: This study introduces the limit of detection (LOD) metric in CEM to quantitatively assess iodine detectability as a function of these imaging variables in a phantom study.

Methods

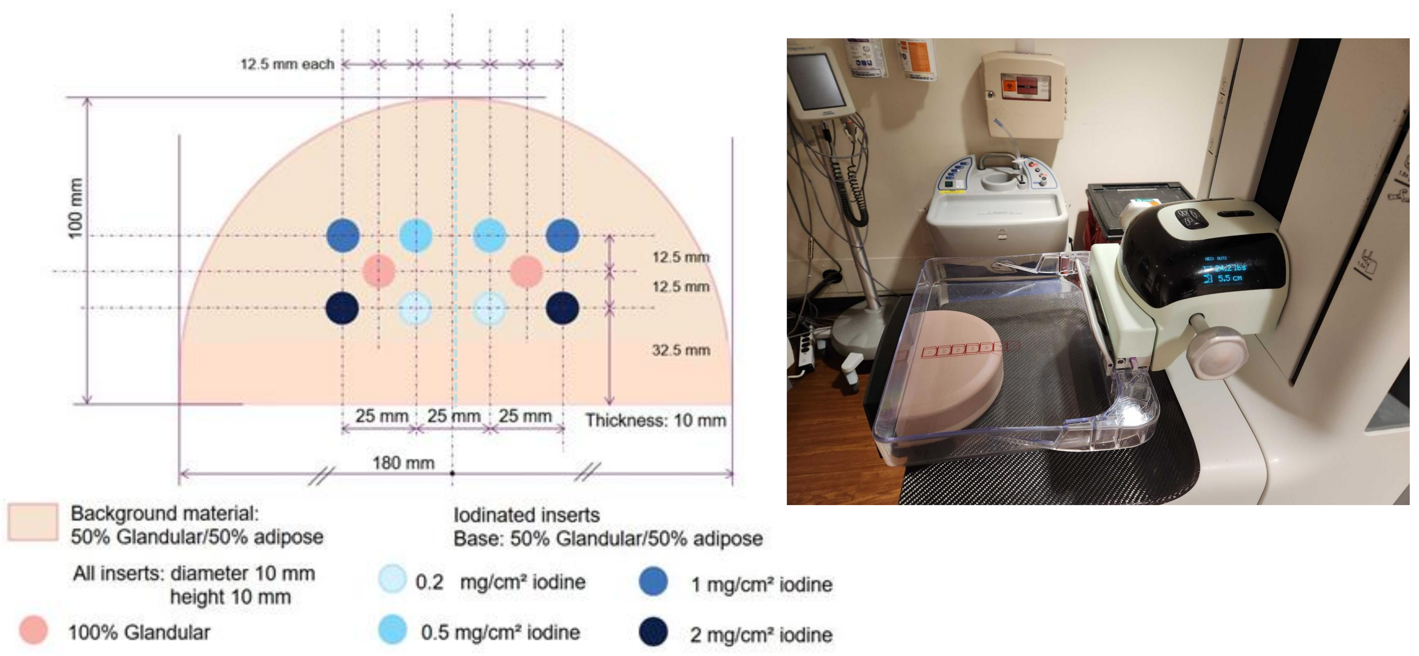

Figure 1: A CEM phantom (CIRS CESM Phantom, Model 022) mimicking breast tissue was used, featuring a 10mm contrast target slab made of a 50/50 glandular-adipose mix with inserts representing iodine surface concentrations of 0.2, 0.5, 1, and 2mg/cm^2.

CEM imaging was performed using a clinical protocol across four phantom tissue densities - BR-GLAND, BR-12, BR-30/70, and BR-FAT, each with tissue thicknesses of 20mm, 40mm, 60mm, and 80mm, added on top of the 10mmtarget slab.

Additionally, imaging dose dependency was assessed at a 40mm thickness for each tissue density by varying the AEC settings.

The LOD metric was estimated from CEM recombination images to assess iodine detectability using following equations[1]:

LOD Estimation

$$LOB_{signal} = \mu_{glandularROI} + 1.645 \times \sigma_{glandularROI}$$

$$LOD_{signal} = LOB_{signal} + 1.645 \times \sigma_{lowest\,Concentration}$$

$$LOD = \ln\left(\frac{(LOD_{Signal} - c_{Intercept})}{c_{slope}}\right)$$

Results

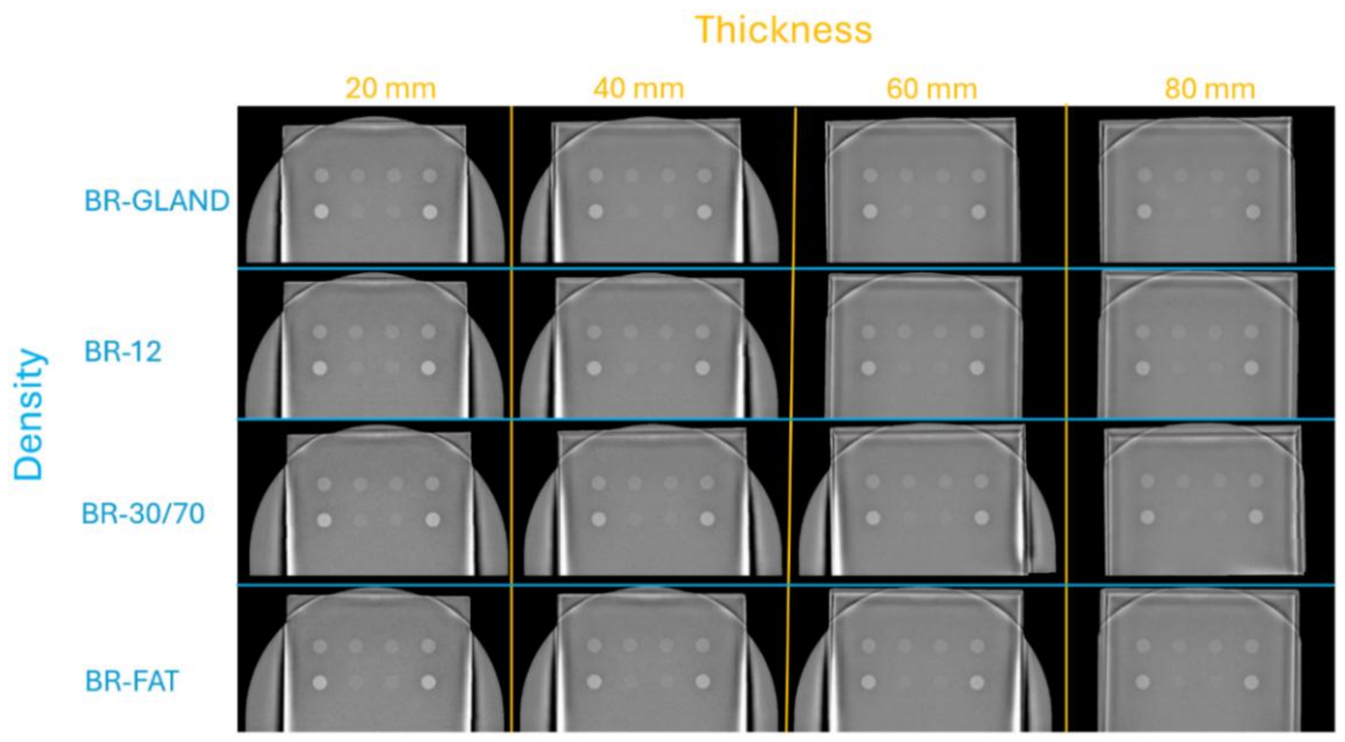

Figure 2: CEM recombination images across varying tissue densities and thicknesses. Each image displays two symmetrical sets of iodine inserts with surface concentrations of 0.2, 0.5, 1.0, and 2.0mg/cm^2. The image acquired with 80mm of BR-GLAND shows incomplete cancellation of the glandular inserts, which are not apparent in the other rest of the images.

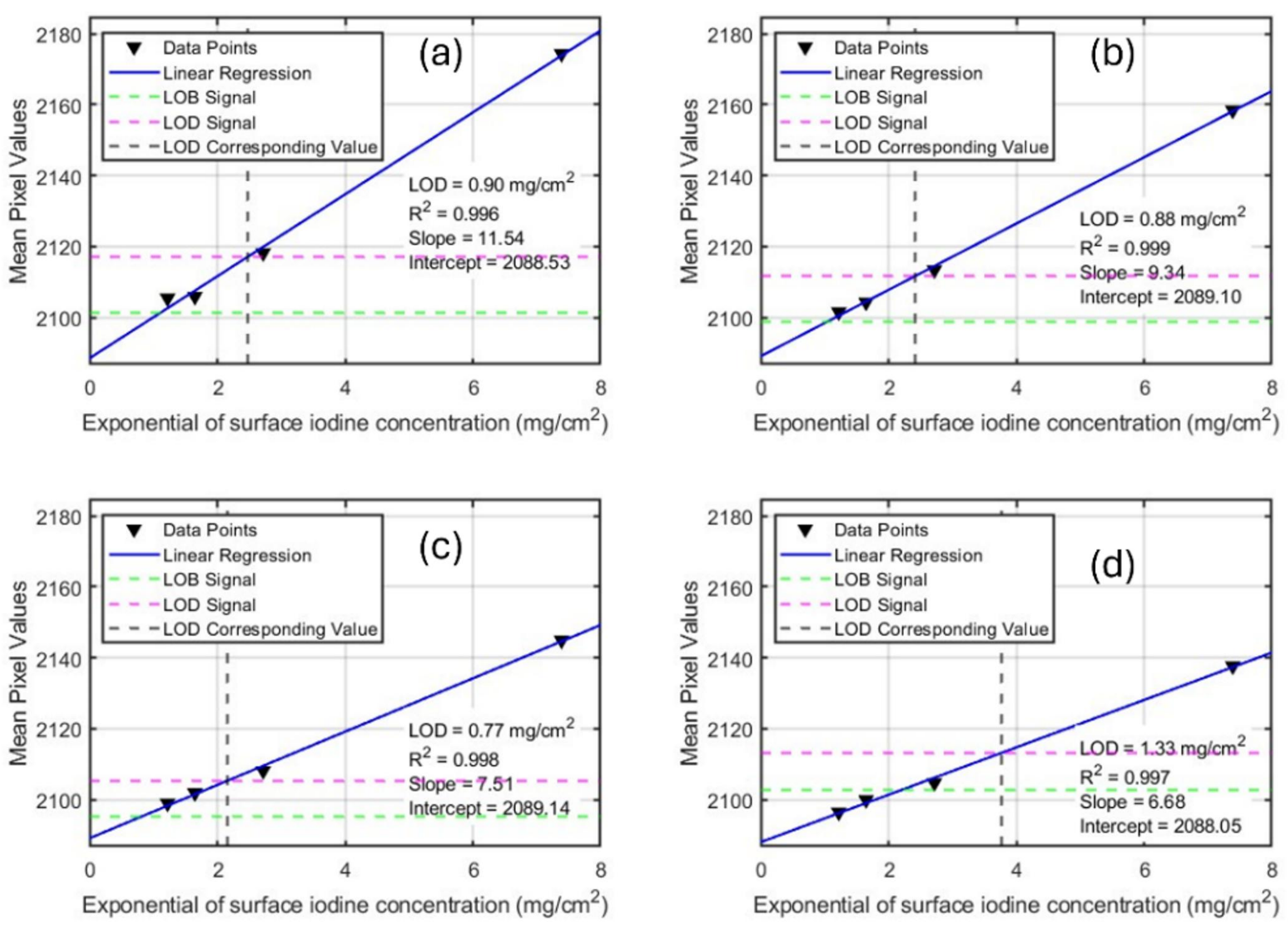

Figure 3: Linear regression and LOD estimation for BR-GLAND across varying thicknesses: (a) 20mm, (b) 40mm, (c) 60mm, and (d) 80mm. The LOD metric indicated that the system's iodine detectability performance is highest (lowest LOD value) at 60mm and lowest (highest LOD value) at 80mm.

LOD Dependency

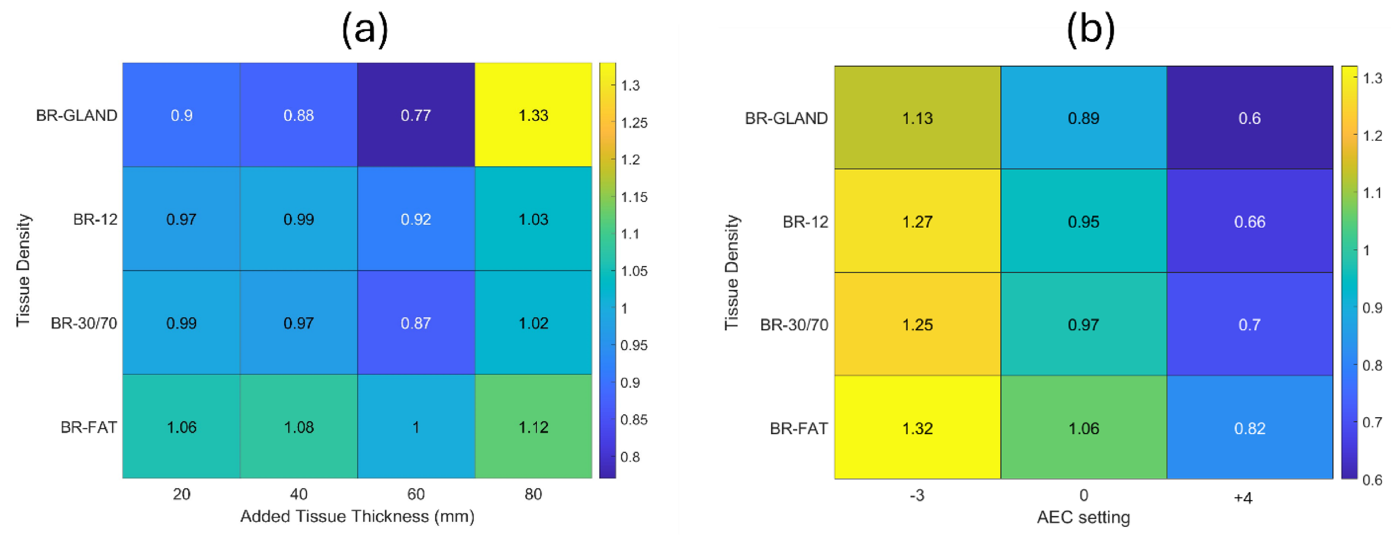

Figure 4: Summary of the LOD dependency as a function of (a) tissue density and thickness, and (b) tissue density and exposure conditions at varying AEC settings (-3, 0, and +4) with an added thickness of 40mm.

Conclusion

- ✓ Introduced the limit of detection (LOD) as a quantitative metric for minimum threshold of iodine detectability in CEM.
- ✓ LOD is affected by imaging variables, including tissue density, thickness, and dose in CEM.
- ✓ LOD can be used to optimize clinical CEM protocol based on patient-specific breast tissue characteristics.

Reference

[1]Clinical and Laboratory Standards Institute. Evaluation of detection capability for clinical laboratory measurement procedures; approved guideline. EP17-A2. 2nd ed. Wayne, Pa: Clinical and Laboratory Standards Institute; 2012.

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Note: This study was conducted at Duke.