Investigation into the Role of Novel Anthropomorphic Breast Ultrasound Phantoms in Radiology Resident Education

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Background: Breast Ultrasound

- Breast ultrasound is a real-time technique used in the evaluation of breast tissue and is highly dependent on technique:
  - Ability to select and manipulate the ultrasound machine settings to optimise the image quality.
  - Ability to thoroughly and accurately scan the breast and identify the area of concern.
  - Knowledge of the acoustic characteristics and recognition of the normal anatomy, pathology and artifacts commonly seen in the breast on ultrasound.
  - Ability to characterize an abnormality and communicate any findings using standard terminology (BI-RADS).

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Background: Benefits of Phantom Models

There are four overall benefits to using medical simulators as a component of medical training:

i. Improved educational experience
ii. Increased patient safety
iii. Cost efficiency
iv. Ongoing training opportunities

Specific Benefits for Resident Education:

- Hands on training in a self-directed and low-stress environment
- Practice in manipulating the ultrasound machine in order to optimize image quality
- Practice in developing scanning techniques for lesion identification and localization
- Practice in identifying normal anatomy, pathology and artifacts commonly found in the breast

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Purpose

- To evaluate the teaching and training role of a novel breast phantom which simulates both the anthropomorphic and sonographic characteristics of the different breast tissues, including benign and malignant breast lesions, in a group of radiology residents at a large academic medical center.
- **Hypothesis**:
  - Hands-on training using anthropomorphic breast phantoms incorporated with a short didactic training session will improve residents' ability to accurately and confidently detect, as well as characterize, breast lesions.

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Materials and Methods: Phantom

- Two similar devices (Phantom 1 and Phantom 2) were designed to produce realistic sonographic images of breast morphology with a range of embedded pathologies.
  - The Phantoms were composed of an agar-based tissue mimicking material with different quantities of glycerol, Aluminum oxide and Silicon carbide particles in order to alter the speed of sound, attenuation and relative backscatter of the different tissue components with the phantom[1].
  - Phantom 1 (P1) and Phantom 2 (P2) were designed to produce realistic sonographic images of breast morphology with a range of embedded pathologies distributed at known locations within the phantom.

Photograph of the anthropomorphic breast phantom training device used in this study

- 9 radiology residents from a large academic medical center were recruited with varying levels of breast ultrasound experience

  4th Year Residents (n=3), 3rd Year Residents (n=3) and 2nd Year Residents (n=3)

1. Cannon LM, Fagan AJ and **Browne JE**, *"Novel tissue mimicking materials for high frequency breast ultrasound applications"* UMB, vol. 37(1) ,122–135, 2011.

Materials and Methods: Training and Assessment

- Each participant underwent:
  - Unguided baseline assessment in identifying and characterizing lesions using Phantom 1
  - 2 hour independent study training session with review of information on:
    - Scanning technique
    - BI-RADS lexicon
    - Ultrasound images of each lesion within PI, along with details of lesion location and characteristic features
  - Unguided final assessment in identifying and characterizing lesions using Phantom 2

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Materials and Methods: Assessment

- Each participant was asked to:
  - Scan Phantom 1 using the ML6-15 transducer with the GE LOGIQ E9 ultrasound machine.
  - Detect/identify any lesions seen.
  - Characterize each lesion based on location:
    - Clock face position (o'clock)
    - Depth (anterior, mid or posterior)
    - Distance from nipple (mm or cm)
  - Characterize each lesion based BI-RADS v5 lexicon
- Identification and characterization of each lesion was documented by an independent observer (Table 1).

Lesion Size	Shape	Margin Contour	Echogenicity	Orientation	Posterior Effects	Calcifications
	Round Oval Irregular	Circumscribed Non-circumscribed - Indistinct - Angular - Microlobulated - Spiculated	Anechoic Hypoechoic Hyperechoic Isoechoic Heterogeneous	Parallel Anti-parallel	None Shadowing Enhancement	Yes No

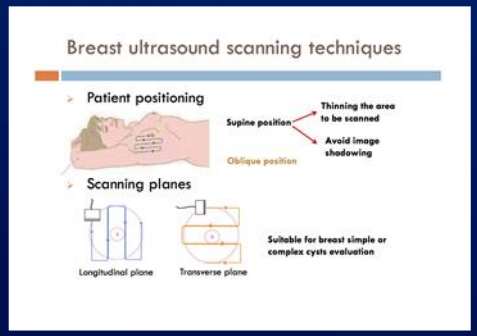
Table 1: Example lesion characterization table used by independent observer.

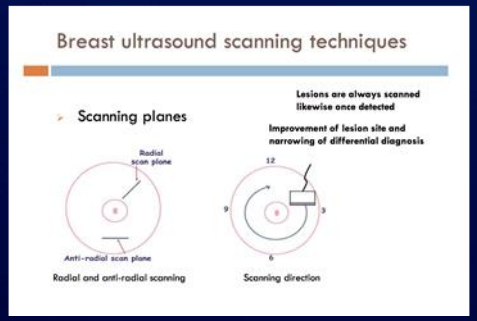
Materials and Methods: Training session

Each participant then underwent a two hour independent study training session. Materials were provided on scanning techniques, Bi-RADS lexicon and phantom specifications

Resident scanning during independent study training session

Scanning technique

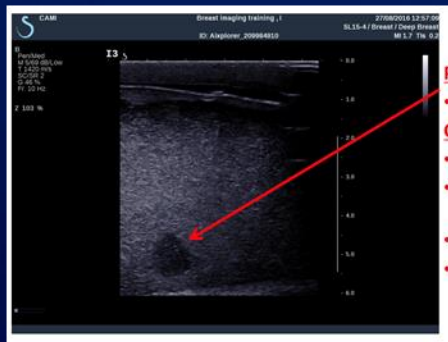




BI-RADS lexicon

ULTRASOUND		
Tissue composition *(screening only)*	a. Homogeneous background echotexture – fat b. Homogeneous background echotexture – fibroglandular c. Heterogeneous background echotexture	
Masses	Shape	Oval
		Round
		Irregular
	Orientation	Parallel
		Not parallel
	Margin	Circumscribed
		Not circumscribed
		- Indistinct
		- Angular
		- Microlobulated
		- Spiculated
	Echo pattern	Anechoic
		Hyperechoic
		Complex cystic and solid
		Hypoechoic
		Isoechoic
		Heterogeneous
	Posterior features	No posterior features
		Enhancement
		Shadowing
		Combined pattern
Calcifications	Calcifications in a mass	
	Calcifications outside of a mass	
	Intraductal calcifications	

Ultrasound images of each lesion within P1, along with details of lesion location and characteristic features



Position: 12 o'clock; Zone 1-2;

- Depth 45-55 mm; Size ~ 12 mm;

Characteristics

- Shape = Irregular;
- Margin = not circumscribed: angular; ill-defined;
- Echo Pattern = Hypoechoic;
- Posterior Acoustic Effects = None

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Results: Lesion Detection

There was a significant increase in residents' detection scores pre- and post-training (pooled $p<0.003$)

2nd years: 29 ± 11%
3rd years: 31 ± 13%
4th years: 19 ± 17%

All residents pooled: 26 ±14%

No significant difference was found in residents' ability to detect the lesions with respect to their year of residency training.

- One 4th year resident repeated the post-training test on a different day to determine repeatability of lesions detected.

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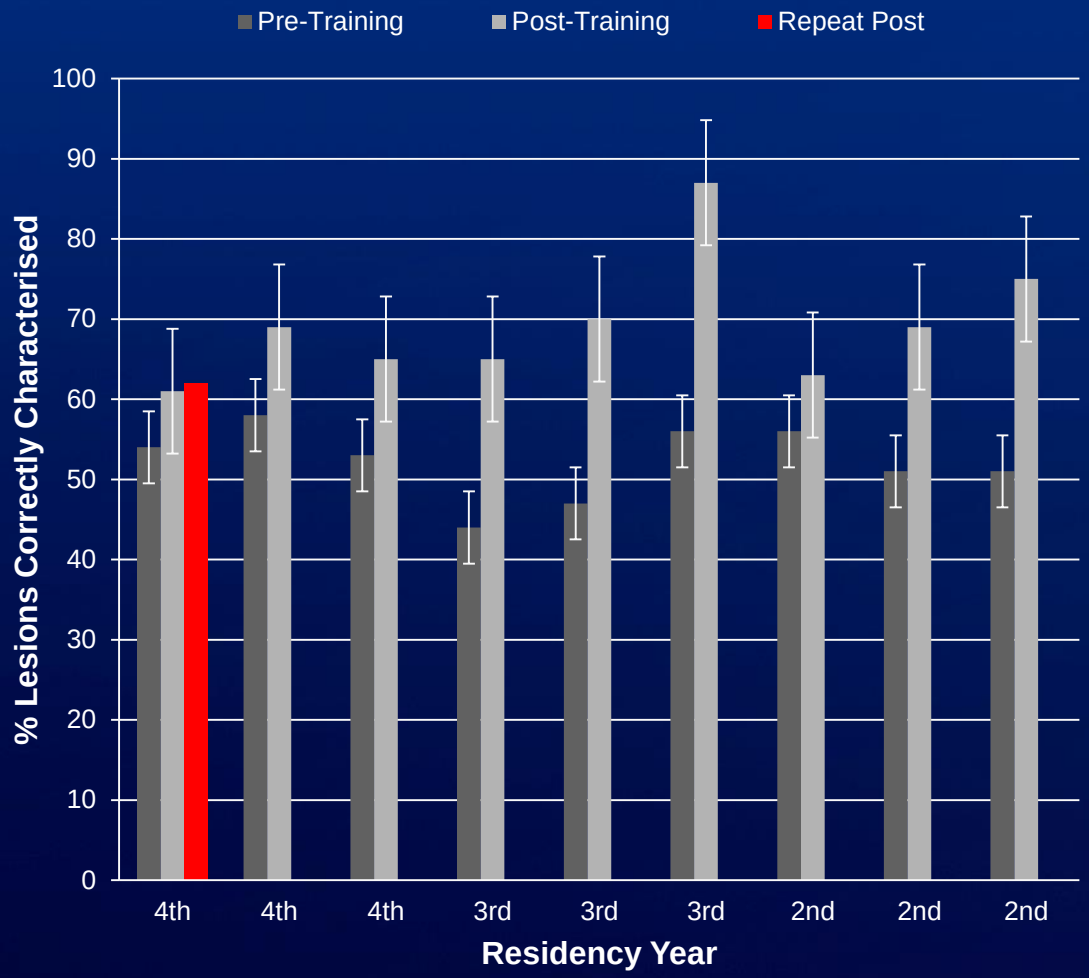
Results: Lesion Characterisation



- Significant increase in the residents' characterization scores pre- and post-training (pooled $p<0.003$)
  - 2nd years: 16 ± 9%
  - 3rd years: 25 ± 5%
  - 4th years: 10 ± 3%

  All residents pooled: 17 ± 8%

- Score was weighted in terms of the number of lesions detected, i.e. if the participant detected only 3 lesions – then the score is based on the correct characterisation of those 3 lesions

One 4th year resident repeated the post-training test on a different day to determine repeatability of lesion characterization.

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Discussion

- This study demonstrates the utility of lifelike ultrasound breast phantoms incorporated with a short training session in the education of radiology residents and their ability to accurately and confidently detect breast lesions.
- There was a significant increase in residents' ability to detect lesions pre- and post-training, with a mean increase of 26 ± 14%, with pooled $p<0.003$.
- There was a significant increase in residents' ability to accurately characterize lesions pre- and post-training, with a mean increase of 17 ± 8%, with pooled $p<0.003$.
- Overall, radiology residents felt the anthropomorphic breast phantoms and training sessions provided a valuable training experience which helped develop self-confidence in both performing and interpreting breast ultrasound exams, while helping to integrate theory and practice.

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Conclusions

- Anthropomorphic breast phantoms were useful for training and assessment purposes by providing a lifelike simulation of breast tissue for ultrasound imaging in a low-stress environment.
- This allowed residents to practice ultrasound imaging without direct exposure to patients, thus refining their ultrasound scanning skills.

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