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Successful Use of a Cadaver Model to Teach Ultrasound-Guided Breast Procedures to Surgical Trainees

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A B S T R A C T

Introduction: In academic breast surgery, ultrasound use tends to be limited to radiology departments, thus formal surgical resident training in breast ultrasound is sparse. Building on residents' ultrasound skills in our general surgery training program, we developed a novel curriculum to teach ultrasound-guided breast procedures (UGBPs), including core needle biopsy (CNB) and wire localization (WL). We hypothesized that learning UGBPs on cadavers would be preferred to learning with a breast phantom model using chicken breasts.

Methods: Residents received a 1-h lecture on breast CNB and WL followed by a 1-h hands-on laboratory session. Olives stuffed with red pimentos were used to replicate breast masses and implanted in chicken breasts and the breasts of lightly embalmed and unembalmed female cadavers. All residents practiced UGBPs with a course instructor on both models. Residents completed anonymous prelaboratory and postlaboratory surveys utilizing five-point Likert scales.

Results: A total of 35 trainees participated in the didactics; all completed the prelaboratory survey and 28 completed the postlaboratory survey. Participant clinical year ranged from 1 to 6. Residents' confidence in describing and performing CNBs and WLs increased significantly on postlaboratory surveys, controlling for clinical year ($P < 0.001$). Eighty-point seven percent preferred learning UGBPs on cadavers over phantoms most commonly citing that the cadaver was more realistic.

Conclusions: Following a novel 2-h UGBP training curriculum using phantom and cadaveric models, resident confidence in describing and performing UGBPs significantly improved. Most favored the cadaveric model and reported that the course prepared them for real-life procedures.

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Introduction

Ultrasound is a valuable tool in clinical breast oncology playing a role in lesion characterization, breast biopsies, tumor localization, and intraoperative excision. Being facile with breast ultrasound empowers surgeons and improves outcomes including decreased margin positivity rates and the need for additional procedures.[1,2]

Despite these benefits, many surgeons underutilize ultrasound and are frequently unfamiliar with ultrasound-guided breast procedures (UGBPs). Breast procedures, however, are an integral part of practice for dedicated breast surgeons and general surgeons alike. In critical access hospitals, for example, breast procedures consist of 3%-7% of surgeon case volume.[3] Therefore, breast procedural skills are essential for all general surgery trainees to develop, especially those that may have future careers where radiology services may be limited such as in rural or other community practice settings.

Unfortunately, breast-specific procedural skills using ultrasound have not always been incorporated into surgeons' training, affecting their use in practice. A Rural Surgeon's Forum questionnaire in 2009 and 2011 reported 52% of surgeons felt little or no confidence performing ultrasound on the breast.[4] Another survey of 873 surgeons who participated in an American College of Surgeons ultrasound course revealed that before the course only 58% of surgeons performed ultrasound examinations.[5] Even a survey of surgeons who graduated from Society of Surgical Oncology–accredited Breast Surgical Oncology fellowship programs between 2005 and 2009 found that 61% of respondents thought they were not well prepared by their fellowship program to perform ultrasound. Only 28% thought they were well prepared to perform an ultrasound-guided biopsy.[6] A more recent study evaluating the benefit and role of a new ultrasound curriculum for surgical trainees found that before the curriculum, only 11.3% of all residents had previous exposure to any formal ultrasound training and all the senior residents reported that they had no prior training.[7] The lack of confidence in trained surgeons, including fellowship-trained breast surgeons, underscores the overall lack of breast ultrasound experience in surgical training.

Ultrasound training deficiency may be explained by the distribution of physicians performing UGBPs. In academic breast surgery, ultrasound is primarily performed in breast imaging departments, thus formal surgical resident training in breast ultrasound is sparse.[8] In an effort to prepare surgical trainees and medical students for UGBPs several courses have been designed. These courses utilize a variety of models to simulate breast tissue and tumors, including pork or turkey tissue with olives, tissue-equivalent needle breast biopsy phantoms, and even Jell-O.[9-11] Only one study utilized fresh cadavers to teach ultrasound-guided breast biopsies; however, these skills were taught to medical students.[12]

At our institution, residents have received faculty-led ultrasound courses including central line placement and extended focused assessment with sonography in trauma exams, yet there is no current curriculum for UGBPs. Fortunately, there is a robust cadaveric skills component incorporated into the resident educational program. Thus, we developed a novel curriculum at our institution to teach UGBPs, including both core needle biopsy (CNB) and wire localization (WL), using common teaching models and cadavers. We hypothesized that learning UGBPs on cadavers would improve trainee confidence performing UGBPs and be their preferred teaching method compared to more standard teaching with a breast phantom model using chicken breasts.

Methods

Study setting & population

Our general surgery program is 7 years with 2 research years incorporated after the second or third clinical year. There are approximately 50 residents total, including research residents. Study participants included general surgery interns and residents (including those in their research years) and a breast surgical oncology fellow. Other interns rotating on general surgery services at the time of the course also participated; these included interns in urology, plastic surgery, and head and neck surgery as well as those in their preliminary year.

During the first session, all residents and off-service interns (but not general surgery interns) present at general surgery conference, excluding those who were postcall or offsite, completed the course. During the second session, general surgery and off-service interns and residents who were unable to participate in the first session and interested in the course were present.

Model & course design

Two breast models were used: (1) lightly embalmed or unembalmed female cadavers and (2) chicken breasts. Fully embalmed cadavers were found to be too rigid to allow for maximum breast ultrasound visibility. Cadavers were provided by the Donated Body Program at the University of California, Los Angeles. Pimento olives were placed in the cadaver breasts and chicken breasts to simulate a breast mass. These olives were chosen because the red center of the Pimento olives allowed for both better visibility in the cadaver model compared to other lesion replicas and allowed for greater accuracy of the biopsies to be evaluated.

Olives were inserted into cadavers by the following technique: using a scalpel, an inframammary incision was made to lift the breast off the pectoralis muscle. Olives were then inserted from the inferior aspect of the breast into each quadrant then sutured in place to prevent displacement. The inframammary incision was reapproximated with towel clamps. A nylon suture was then placed through the skin of the breast to mark the location of each olive for ease of instruction. Approximately three to four olives were placed in each cadaver breast and chicken breast depending on breast volume, such that the olives were not abutting. See Figure 1 for images of olives in cadaver and chicken breasts.

A 2-h course was designed to teach surgery trainees how to perform two UGBPs including CNB and WL. This course was conducted during the weekly general surgery conference that

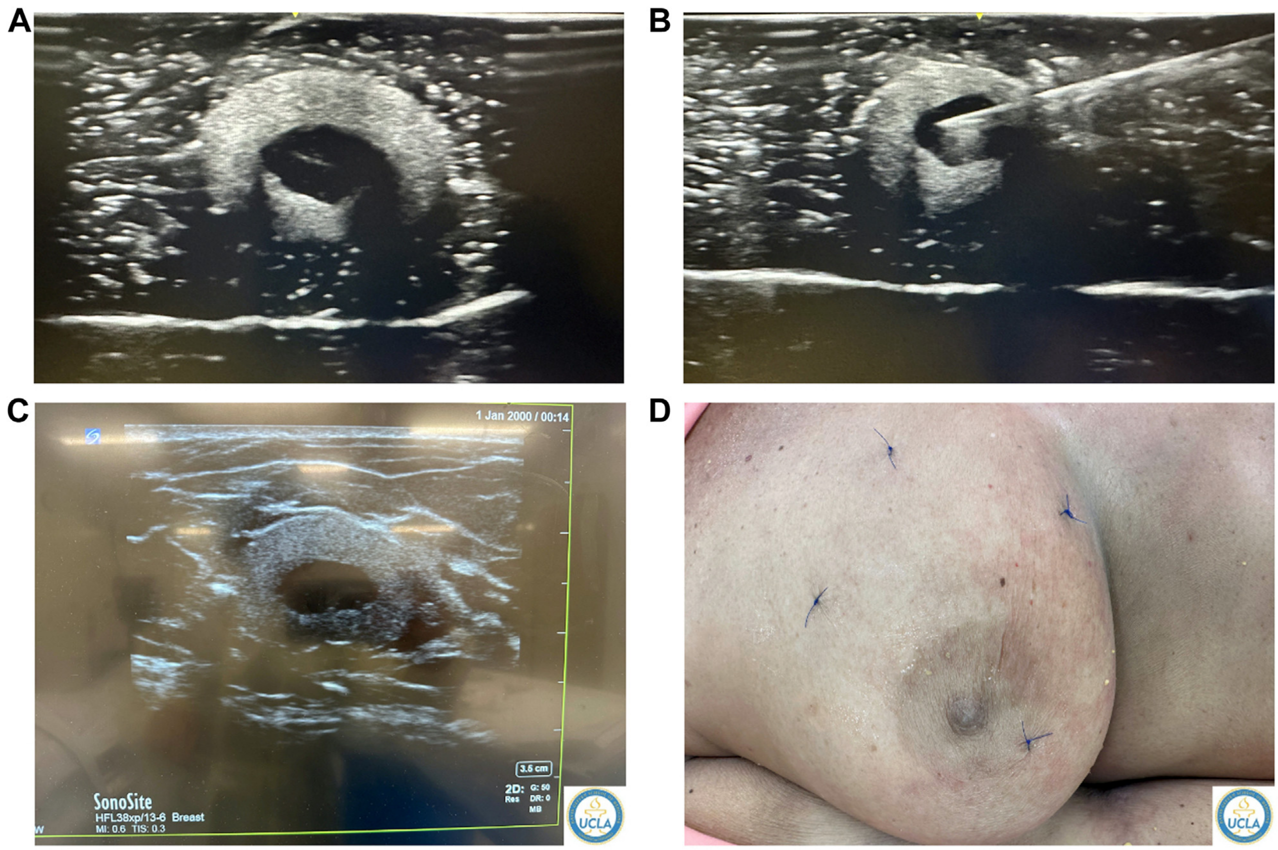

Fig. 1 – Images of olives in chicken breast and cadaver breasts. (A) Ultrasound images of olive in chicken breast and (B) undergoing WL. (C) Ultrasound image of olive in cadaver breast. (D) Cadaver breast after implantation of olives.

includes protected education time. The first hour consisted of an interactive didactic session describing the use of ultrasound in breast surgical oncology, the ultrasound appearance of various breast pathologies, and ultrasound scanning and biopsy technique. During the second hour, trainees performed CNBs with 14-gauge spring-loaded needles and WLs with 20-gauge needles and 5-7-cm wires in lightly embalmed or unembalmed cadaver and phantom models (i.e., chicken breast). Trainees were supervised by breast surgery faculty and breast industry technicians with approximately one supervisor for four to six trainees at each station depending on the session. Trainees were supervised performing UGBPs on both models. Half of trainees started the session using the cadaver models while the other half started with the phantom models. After 30 min, trainees switched models. Procedure success was not differentiated between models.

Due to the interest and resident satisfaction of the first session, a second session was offered 2 mo later to interns and trainees who were unable to participate in the first session. Assessment of procedural success was not included in the second session surveys.

Data collection and analysis

Residents completed anonymous prelaboratory and postlaboratory paper surveys, using 5-point Likert scales. Prelaboratory and postlaboratory paper surveys were completed immediately before and after the laboratory, respectively. See Table A.1 for prelaboratory and postlaboratory survey questions. Data were analyzed using a two-sample *t*-test. Specifically, Likert scale data were analyzed using a nonparametric test, Mann–Whitney *U* test, for unpaired data, and ordered logit. Missing or illegible data were excluded from analysis.

Verbal informed consent was obtained from all participants. This study was certified exempt by our Institutional Review Board (IRB #23-000933).

Results

Two separate didactic and laboratory sessions were conducted during protected resident education time. A total of 35 trainees (24 in the first and 11 in the second session) participated in the didactic session and completed the prelaboratory survey. Twenty-eight trainees (20 in the first and eight in the second session) completed the postlaboratory survey. One prelaboratory survey was excluded as it was incorrectly completed; 34 participants (24 in the first and 10 in the second session) were included for analysis. Two postlaboratory surveys were excluded because the participants did not participate in the didactic session; 26 participants (20 in the first and six in the second session) were included for analysis.

Participating trainee levels ranged from clinical year 1 to 6 (median clinical year 3 for prelaboratory and postlaboratory

Table 1 – Baseline characteristics of trainees.

Variable	Prelaboratory survey	Postlaboratory survey
Number of survey participants	34	26
Session participants, N (%)		
1	24	20
2	10	6
Clinical y, median	3	3
1	8 (23.5)	5
2	5 (14.7)	5
3	9 (26.5)	9
4	4 (11.8)	2
5	7 (20.6)	4
6	1 (2.9)	1
Previous formal ultrasound training	23 (67.6%)	
Number of ultrasound-guided procedures performed, N (%)		
0	3 (8.8%)	
1-3	6 (17.6%)	
4-5	2 (5.9%)	
≥6	23 (67.6%)	
Number of UGBPs performed, N (%)		
0	24 (70.6%)	
1-3	6 (17.6%)	
4-5	2 (5.9%)	
≥6	2 (5.9%)	
Number of breast surgeries that you have participated in, N (%)		
0	3 (8.9%)	
1-3	2 (5.9%)	
4-5	0 (0.0%)	
≥6	29 (85.3%)	
Number of breast lumpectomies with presurgical placement of a localization device that you have participated in, N (%)		
0	4 (11.8%)	
1-3	2 (5.9%)	
4-5	1 (2.9%)	
≥6	27 (79.4%)	

cohorts, $P = 0.85$). Most trainees ($n = 23$, 67.6%) had previously attended faculty-led ultrasound teaching (Table 1). Twenty-three residents (67.6%) had performed six or more ultrasound-guided procedures including central line placement or chest pigtail placement, while two (5.9%) performed four to five, six (17.6%) performed one to three, and three (8.8%) performed none. A majority of residents ($n = 31$, 91.2%) had exposure to breast surgeries including lumpectomies. Twenty-nine point four percent of residents performed at least one UGBP; however, this included breast abscess incision and drainage procedures. All residents who completed the first session performed CNB successfully, capturing the red pimento from the center of the target in at least one model. Seventy-three point seven percent (14 of 19) of trainees successfully performed a WL within the time allotted (one did not attempt a WL).

Following the course, residents' confidence rating significantly increased from prelaboratory to postlaboratory surveys in describing, as well as in performing, both CNBs and WLs on both univariate analysis ($P < 0.001$ for all survey questions) and multivariable analysis ($P < 0.001$ for all survey questions). See Figure 2 for distribution of survey answers prelaboratory and postlaboratory. On multivariate analysis, clinical year of training was associated with increased improvement in confidence describing and performing CNB and WL ($P = 0.001$-0.021 for all four questions). However, participation in the first or second course did not impact confidence responses ($P = 0.59$-0.96 for all survey questions).

Regarding resident satisfaction, 80.7% ($n = 21$) preferred learning UGBP on cadavers over phantoms, 11.5% ($n = 3$) preferred to learn on both models, and 3.8% ($n = 1$) preferred the phantom model. One participant's response was illegible. The most common reason for preferring cadavers was that it was more realistic (66.7%, 12 of 18 responses).

Ninety-six percent of trainees who participated in both the didactic and corresponding laboratory session rated the course as excellent ($n = 18$) or good ($n = 7$), and most (77%, 20 of 26) thought the course prepared them for real-life procedures. When asked how the course prepared them for real-life operations, practical experience ($n = 8$ of 19) and tool or technique familiarization ($n = 6$ of 19) were the most cited reasons. More time in the laboratory session was the most common area for improvement proposed by participants (7 of 17 responses). See Figure 3 for the distribution of participant preferences and feedback.

Discussion

After completion of a 2-h course, trainees reported significantly improved confidence in both describing and performing UGBPs. While increasing clinical year of training was associated with increasing confidence, all surveyed trainees from the main session reported they were able to successfully biopsy the target lesion and most were able to perform a WL. Most trainees had previous ultrasound experience including ultrasound-guided non-breast interventions, suggesting that this prior experience likely enhanced overall performance and confidence.

A unique aspect of our study design is that, unlike earlier studies, we used a breast cadaver model in addition to previously published phantom models to train residents. In our review, we identified only one previous study that reported using a cadaveric model to teach breast ultrasound biopsy.

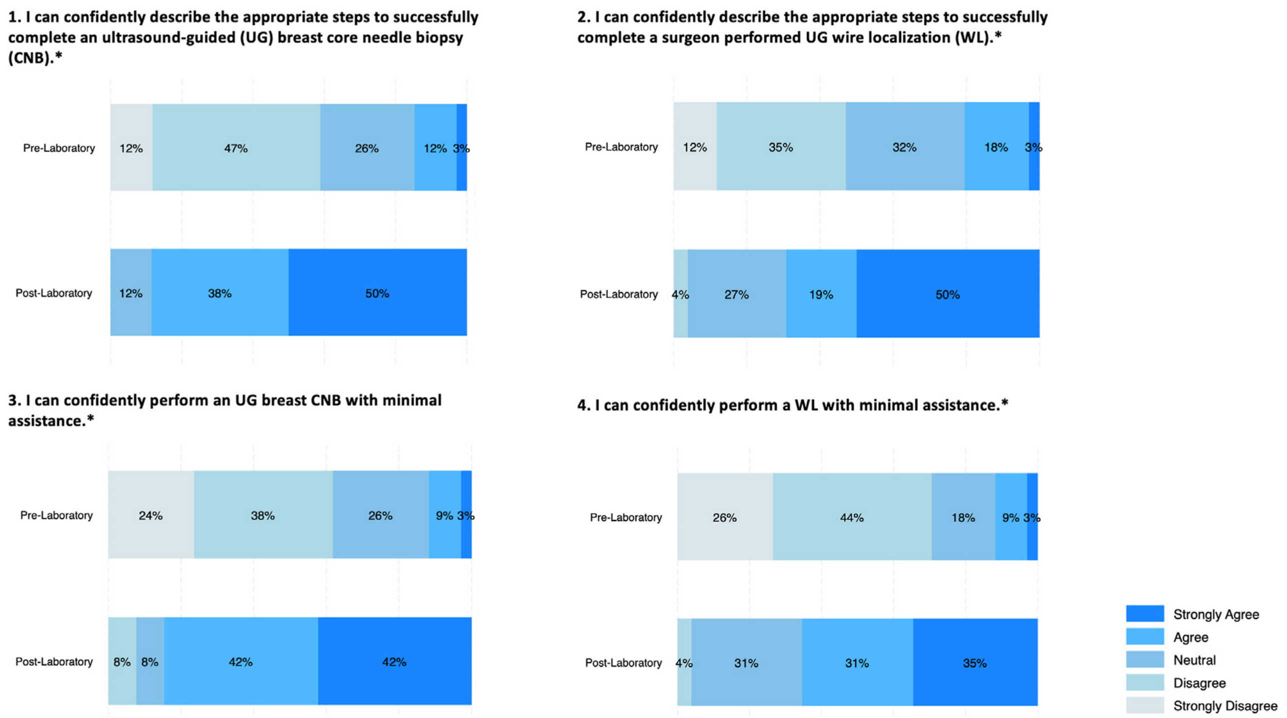

Fig. 2 – Survey responses on confidence of UGBPs prelaboratory and postlaboratory (34 prelaboratory and 36 postlaboratory responses). *Wilcoxon rank sum test $P < 0.001$ for statements 1-4.

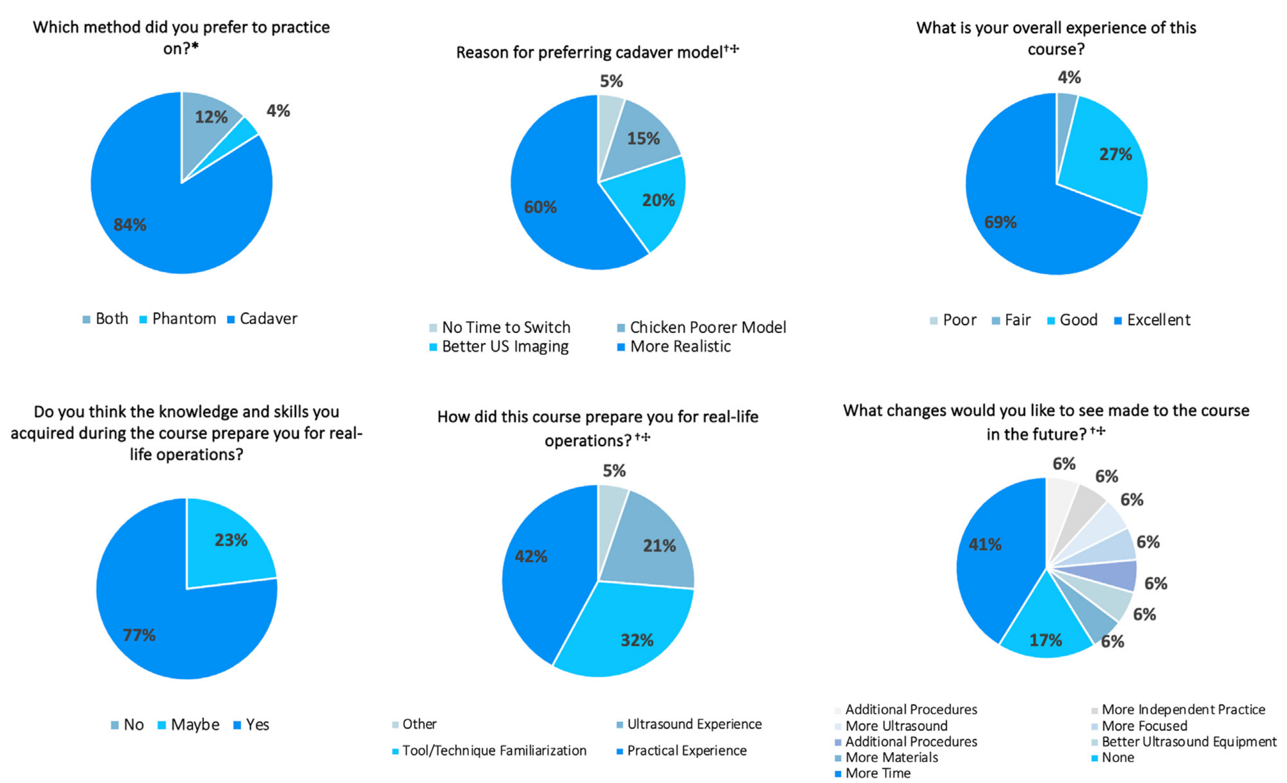

Fig. 3 – Participant preferences and feedback obtained from postlaboratory survey completed by a total of 26 participants. *One participant excluded as answer was unrelated; †Free response answers categorized into groups; ✣Unanswered or illegible questions excluded from total.

However, this was used to train medical students rather than surgical trainees.[12] Compared to other learning modalities such as simulators, animate laboratories, lectures, and other techniques, surgical residents ranked cadaver sessions best for "increasing confidence in performing a procedure and for learning the steps of an operation" according to a study by Lewis, *et al*.[13] Likewise, we found that 80.7% of participants preferred learning with the cadaver model compared to the phantom model. Thus we demonstrate that our cadaver model is the preferred model for learning UGBPs when compared to a more common model.

By providing surgery trainees with the skillset to perform UGBPs, we hope to enhance their confidence and utilization of these UGBPs in their careers. Research demonstrates that being facile with UGBPs does not simply enhance a surgeon's toolkit for assessing and diagnosing breast lesions but also improves surgical outcomes and efficiency when performed by surgeons. General and breast surgeons located at critical access hospitals and regions with limited access to healthcare services would be most likely to apply these skills. By performing in-office biopsies and their own WLs for ultrasound visible masses, they could potentially reduce biopsy wait times and reduce the workload of radiologists, overcoming the negative effects of resource limitations.

In a study by Shin *et al.* in Korea, surgeon-performed intraoperative ultrasound-guided WLs (IOWLs) were compared with preoperative WL performed by radiology in nonpalpable breast lesions. While the margin positivity rates, conversion rates, and reoperation rates were equivalent, excision volume and widest tumor-free margin were significantly smaller in the surgeon-performed IOWL cohort. Notably, the procedure time was significantly shorter for the surgeon-performed IOWLs (mean of 8 min compared to 45 min; $P = 0.002$) compared to the radiology-performed preoperative WLs.[14] Surgeon-performed IOWLs enable these procedures to be performed while the patient is comfortably sedated rather than preoperatively. In addition, our own group evaluated margin positivity rates after 137 patients with breast cancer underwent IOWL and reported a 7.3% margin positivity rate even though 15.4% of the study population underwent non–ultrasound-guided core needle biopsies.[15] Though performing IOWLs would increase surgical time and time under anesthesia, these studies demonstrate the positive surgical outcomes of surgeon-performed procedures and the logistical advantages highlighting the benefit of surgeon-performed UGBPs and hence the importance of adequate surgeon training.

Multiple studies also show benefit of intraoperative ultrasound guidance without WL for breast conservation surgery. Not only is this technique considered patient-friendly and to have lower costs since no preoperative procedure or localization marker is required, but it also has decreased margin positivity rates and decreased reoperation.[1,16,17] A randomized controlled trial comparing ultrasound-guided surgery to palpation-guided surgery also demonstrated reduced tumor-involved resection margins and smaller excision volumes.[2] Other studies have shown the cost and patient benefit of using ultrasound visible biopsy clips at time of breast biopsy allow for increased use of intraoperative ultrasound-guided localization.[18,19] These studies highlight the potential of UGBPs and ultrasound guidance in breast surgery in general. They also point to ultrasound-guided lumpectomies as an additional area of breast surgery resident training.

Our study has several limitations. First, our cadaver model may have decreased generalizability due to high cost and required resources. Cadavers are limited, costly, and often only available at surgical programs associated with medical schools or training institutions, and lightly embalmed cadavers may be even less available. At our institution, the University of California, Los Angeles Donated Body Program and Surgical Science Laboratory (cadaver lab) are comprehensive and well-established, being used by medical students, residents, and attending physicians of all specialties for training and education purposes. Programs without donated body programs may consider using alternative models, such as the chicken breast model, or collaborating with other institutions that have such programs. Second, while our study demonstrates increased trainee confidence following the course, the course was not intended to evaluate resident skill or ability. Third, our study was performed at a single institution with a small number of participants and not all participants completed all parts of the study.

Given the overall satisfaction of the use of our lightly embalmed cadaver model to teach UGBPs, we intend to expand on this course. Future directions include the development of an objective assessment of resident skills and knowledge prelaboratory and postlaboratory, additional didactic sessions, and intraoperative assessments based on direct observation by breast faculty. Lastly, given the patient, surgeon, and logistical benefits of UGBPs, future studies should compare localization times, operative times, accuracy of breast mass localization, and patient experience between surgeons' intraoperative WLs and preoperatively performed localizations.

Conclusions

Following a 2-h UGBP training curriculum using phantom and cadaveric models, participant confidence in describing and performing UGBPs significantly improved after the course. Most participants felt that the cadaveric model was preferable. Further studies are needed to investigate transferability of these skills to clinical practice.

Supplementary Materials

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jss.2024.07.055.

CRediT authorship contribution statement

Tess C. Huy: Writing – review & editing, Writing – original draft, Visualization, Supervision, Investigation, Formal analysis, Data curation. **Carlie K. Thompson:** Writing – review & editing, Supervision. **Aletta Deranteriassian:** Writing – review & editing, Resources, Project administration. **Warwick Peacock:** Writing – review & editing, Resources. **Areti Tillou:** Writing – review & editing. **Jennifer L. Baker:** Writing – review

& editing, Supervision. **Danielle S. Graham:** Writing – review & editing. **Grace Chang:** Writing – review & editing, Resources. **Nimmi S. Kapoor:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation.

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