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A decade of intraoperative ultrasound guided breast conservation for margin negative resection – Radioactive, and magnetic, and Infrared Oh My…

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ABSTRACT

Background: The oncologic goal of margin-negative breast conservation requires adequate localization of tumor. Intraoperative ultrasound remains most feasible but under-utilized method to localize the tumor and assess margins.

Methods: A prospectively maintained breast cancer database over a decade was queried for margin status in breast cancer patients undergoing breast conservation. Techniques of tumor localization, margin re-excision and closest margins were analyzed. Rate of conversion to mastectomy was determined.

Results: Of the 945 breast cancer patients treated at a university-based Breast Center of Excellence between January 1, 2009 and December 31, 2018, 149(15.8%) had ductal carcinoma in situ; 712(75.3%) had invasive ductal carcinoma, and 63(6.7%) had invasive lobular carcinoma. Clinical stage distribution was: T1 = 372(39.4%); T2 = 257(27.2%); T3 = 87(9.2%). Five hundred and eighty three (61.7%) patients underwent breast conservation. The median (25th −75th centile) closest margin was 6(2.5, 10.0) mm. Thirty five (6.0%) patients underwent margin re-excision, of which 9(25%) were converted to mastectomy. Tumor localization was achieved with ultrasound in 521(89.4%) patients and with wire localization in 62(10.6%) patients. The median (25th-75th centile) closest margin with wire localization was 5.0(2.0, 8.5) mm versus 5.0 (2.0, 8.0) mm with ultrasound guidance [p = 0.6635]. The re-excision rate with wire localization was 14.5% versus 4.9% with ultrasound guidance [p = 0.0073]. The unadjusted Odds Ratio (95% CI) for margin revision in wire localized group compared with ultrasound was 3.2 (7.14, 1.42) [p = 0.0045]; multivariate adjusted OR (95%) was 4(9.09, 1.7) [p = 0.0013].

Conclusions: Ultrasound guidance for localization of breast cancer remains the most effective option for margin negative breast conservation.

Introduction

The oncologic goal of breast conserving surgery in early stage breast cancer is complete resection of the known lesion/s with negative margins while preserving the cosmetic appearance of the breast. Positive margins are associated with twice the rate of local recurrence compared with that for negative margins.[1] In addition, a return to operating room to achieve negative margins is associated with additional risk of anesthesia, surgical complications, cost of care and a high rate of conversion to bilateral mastectomies.[2] Clearly, to achieve the stated oncologic goal with one surgery, surgeons need to precisely identify the location of the lesion within the breast so that appropriate tissue around the lesion can be resected to accomplish negative margins with maximum preservation of cosmetic outcome. Wire-localization (WL) has been is the oldest and most established technique of lesion localization within the breast.[3] This involves a hooked wire placed at the site of the lesion (identified by a clip or other imaging abnormalities) by the radiologist under stereotactic or ultrasound guidance on the morning of surgery under local anesthesia. The surgeon subsequently interprets the two-dimensional images with wire in place

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to resect the target lesion. Despite decades of use, this technique poses several problems: (i) Need for excellent coordination between surgery and radiology schedules,[4] (ii) The approach of wire placement may impact the choice of incision and hamper cosmetic outcome,[5] (iii) Wire displacement, fractures and retention,[6] and (iv) Most importantly, high rate of re-excision.[4] Therefore, there has been a constant push for improving the method of localization of non-palpable breast lesions.

Intraoperative ultrasound (IOUS) was one of the first techniques reported by Schwartz et al., in 1988 for localization of non-palpable breast lesions to explore if the above issues associated with WL could be ameliorated.[7] A decade later, a few more reports[8,9] including a randomized trial,[10] documented success of lesion localization and adequate margin of resection. There have been sporadic publications since then that consistently show excellent identification and margin negative rates for palpable[11–14] and non-palpable[12,15,16] breast cancers using IOUS. Recently, even the cancers that are not originally visible by ultrasound have been resected successfully by intraoperative visualization of the iatrogenic hematoma created by the stereotactic biopsy.[17,18] Despite these results, there has been a constant push to find other localization techniques[4,16] mainly because of difficulty with skills training across disciplines of radiology and surgery that have kept many surgeons from embracing breast ultrasound in their practice.[19,20]

This paper reports the role of ultrasound guidance in achieving negative margins in breast conservation and delineates the characteristics and frequency of breast lesions that are amenable to such an approach over a decade at a university based breast center. This audit also identifies the group of patients not suitable for ultrasound guidance for whom the cost-effectiveness and risk-benefit of newer localization techniques must be compared with traditional wire localization.

Material and methods

A prospectively maintained breast cancer database between January 1, 2009 and December 31, 2019 was queried to identify all patients undergoing breast conservation. Baseline characteristics included patient's age, cancer type, stage and tumor markers. Lesion localization rationale and approach was documented. IOUS guidance was compared to WL to identify the patient selection criteria for each technique and compute the difference in margin re-excision rate and closest margin of resection as outcome measures. Tumor volume and resection volume was also measured.

Ultrasound guided resection technique: A high frequency linear array ultrasound probe was used intraoperatively to identify the lesion. Superior, inferior, medial and lateral margins were marked on the skin at 10 mm distance from the sonographic edge of the lesion. Distance from the skin was used to determine whether the skin anterior to the lesion needs to be resected (<10 mm). Pectoral fascia was routinely excised for posterior margin. Once the lesion is excised, ex-vivo ultrasound was done to confirm adequate margin. A shaved margin was taken if the ex-vivo ultrasound revealed <10 mm distance from the edge of the lesion. Shaved margin during the same surgery was not counted as margin revision. IOUS was not used in WL cases.

Statistical analyses: Four surgical groups were identified: (i) IOUS guided breast conservation, (ii) WL breast conservation, (iii) mastectomy, and (iv) no surgery. The focus of this report is the patients that underwent breast conservation. The two breast conservation groups, (i) IOUS guided, and (ii) WL were compared using Fisher's exact chi-square tests for categorical characteristics such as cancer stage, and using Wilcoxon-Mann-Whitney rank sum test for continuous characteristics such as age at diagnosis. Covariate-adjusted comparisons for the two breast conservation groups were obtained using binomial logistic regression for margin revision (yes/no) and analysis of covariance (ANCOVA) for tumor volume, resection volume, and closest margin; tumor volume and resection volume were natural log-transformed for ANCOVA due to right skewness. Covariates included: age at diagnosis, T stage, neoadjuvant chemotherapy, cancer type, and tumor volume (the latter included only for modeling margin revision).

Results

A total of 945 patients with breast cancer were treated during the study period. Five hundred and eighty three (61.7%) patients underwent breast conservation. Three breast surgical oncologists were involved; albeit ~90% of cases are represented by a single surgeon practice. Table 1 explains the imaging characteristics of the lesions that underlie the choice of localization technique used. Five hundred and twenty one of the 583 patients (89.4%) were able to undergo breast conservation with IOUS guidance; 66 (12.7%) of these patients had cancers that were not visible on ultrasound at the outset, however, the iatrogenic hematoma from stereotactic biopsy was targeted with IOUS. Only 62 of 583 (10.6%) patients had cancers that necessitated a WL approach over 10 years due to extent of calcifications or non-visualization of hematoma or lesion by the time of surgery. Table 2 delineates the imaging characteristics of tumors that were selected for IOUS guided versus WL breast conservation. Interestingly, 181 (31.0%) of lesions had a biopsy clip marketed as sonographically visible; this included 21 patients who underwent WL. There were no statistically significant differences between the two groups in terms of tumor types, biological characteristics, and stage at presentation. Table 3 outlines the differences in the outcome measures between IOUS guided and WL breast conservation. Margin revision was performed to achieve adequate resection in only 5% (26) of IOUS guided excisions compared with 14.5% (9) of WL surgeries [$p = 0.0073$]. Closest margin and volumes of tumor and resected specimens were similar in both groups. Table 4 shows the multivariate binomial logistic regression analysis adjusting for confounders such as age, tumor type, volume, stage and response to chemotherapy. Patients undergoing IOUS guided breast conservation were 70–80% less likely to need a margin revision compared to those subjected to WL surgery irrespective of covariates [$p = 0.0013–0.0045$], albeit selection bias for the choice of WL for extensive microcalcifications cannot be eliminated. Statistically significant confounders modeled in multivariate logistic regression analysis include T stage [Tis or Ductal carcinoma in situ (DCIS) more likely to need margin revision ($p = 0.0001$), and use of neoadjuvant chemotherapy less likely to need margin revision ($p = 0.017$)].

Customary practice at the study institution was margin revision for <2 mm margin before the consensus guidelines on margin revision adopted 'no ink on tumor' as a standard for adequate margin of breast conservation for invasive breast cancers.[21] Therefore, margin data was analyzed to compute the difference before and after the practice changing guidelines (before March 2014; and after March 2014).

In 189 lumpectomy patients diagnosed before March 2014, re-excision of margin occurred in 5.8% ($n = 11$) overall; 3.5% (6/174) in IOUS guided resections and 33.3% (5/15) of WL resections. Fisher's exact p-value comparing IOUS with WL was 0.0006. In 394 lumpectomy patients diagnosed after March 2014, re-excision of margin occurred in 6.1% ($n = 24$) overall; 5.8% (20/347) in IOUS guided resections and 8.5% (4/47) of WL resections. Fisher's exact p-value comparing IOUS with WL was 0.5102. Fisher's exact p-value comparing re-excision rates before and after guideline change is 0.2927 for IOUS guidance, and 0.0308 for WL implying significant impact of guideline change on WL approach (tumors with extensive

Table 1
Rationale for localization technique and characteristics of lesion necessitating the choice.

Breast Conservation Surgery (n = 583)[a]			
Ultrasound guided (n = 521)		Wire localized (n = 62)	
Palpable tumors	191 (36.7%)	Bracketing for extensive microcalcifications	35 (56.4%)
Not Palpable but visible on ultrasound	264 (50.7%)	Sonographically visible hematoma but microcalcifications extended beyond the biopsy cavity needing a wire	19 (30.6%)
Not visible on ultrasound but sonographically visible hematoma after stereotactic biopsy	66 (12.7%)	Biopsy hematoma resolved by the time of surgery requiring a wire	8 (13.0%)

[a] 181/583 (31.0%) of patients had one of the 5 commercially available sonographically visible clips.

microcalcifications). The p-value for effect modification of the IOUS versus WL before and after guideline change is 0.0130 confirming significant difference between two techniques to be more pronounced before than after the change.

Newer techniques report comparison of the investigative technique with WL for non-palpable tumors irrespective of sonographic visibility. Therefore, data for both the IOUS guided and WL resections was compared to the newer techniques reported in the literature, including radioactive seed localization,[22–25] radar localization,[26,27] and magnetic seed localization.[28] Rate of margin revision reported in these studies was compared to the IOUS guided and WL breast conservation in the current paper as depicted with Fisher exact test in Table 5. Clearly, WL resection in select cases where ultrasound is not feasible, is comparable to radioactive seed localization, magnetic seed localization, and radar localization in unslelected cases reported in the literature. IOUS guidance was statistically significantly better in 2 of 4 studies on radioactive seed localization, 1 of 2 radar seed localization studies, and the magnetic seed localization study. WL in the current study was superior to all but 2 studies on these techniques albeit not statistically significant. Margin revision with WL in the current paper was significantly higher than seed localization reported by van Riet et al. in unslelected cases.

Discussion

Use of IOUS for breast conservation since the first report by Schwartz et al.,[7] has consistently shown almost 100% efficacy for identification of non-palpable sonographically visible tumors.[29] Moreover, several studies published between 1999 and 2011 consistently show a negative margin rate of above 88% with lower volume of excision of healthy breast tissue to preserve cosmetic outcome.[29] In the COBALT trial, Krekel et al. showed that the intraoperative use of ultrasound for palpable tumors is associated with 15% reduction in positive margins.[11] Long-term outcomes of this trial confirm the superior cosmetic outcome and patient satisfaction with this approach.[30] To our knowledge, the current audit represents the largest study where IOUS was used for breast conservation comprising of 37% palpable tumors (n = 191), 50% non-palpable-sonographically visible tumors (n = 264), and 13% tumors that were not sonographically visible and iatrogenic hematoma was targeted (n = 66). Margin revision rate of 5% in IOUS guided breast conservation in this series is among the lowest in literature. There are key aspects worthy of discussion regarding incorporation of IOUS for breast conservation:

Patient selection bias: This paper reports the margin revision rates for both IOUS and WL breast conservation. However, these groups were not similar in terms of imaging profile; WL was employed only when ultrasound was deemed not feasible, for example when microcalcifications extend beyond the index lesion.

Table 2
Baseline characteristics of patients undergoing breast conservation.

Breast Conservation Surgery (n = 583)			
Characteristics	Localization Technique		P Value
	Ultrasound guided [n = 521] N (%)	Wire localized [n = 62] N (%)	
Age – median (25th, 75th percentile)	61.82 (52.66, 69.31)	59.02 (54.56, 65.64)	0.4128
Type of cancer			
Ductal carcinoma in situ	88 (16.9)	14 (22.6)	0.6976
Invasive ductal carcinoma	388 (74.5)	42 (67.7)	
Invasive lobular carcinoma	30 (5.8)	4 (6.5)	
Other	15 (2.9)	2 (0.4)	
T stage			
Tis	86 (16.5)	16 (25.8)	0.3212
1	276 (53.0)	26 (41.9)	
2	127 (24.4)	18 (29.0)	
>3	32 (6.1)	2 (3.2)	
N Stage			
0	421 (80.8)	45 (72.6)	0.5513
1	54 (10.4)	8 (13.0)	
>2	46 (8.8)	9 (14.5)	
Biological Markers			
ER positive	423 (81.2)	46 (74.2)	0.1892
PR positive	362 (69.5)	42 (67.7)	0.7789
HER2 receptor	77 (14.8)	10 (16.1)	0.5972

Table 3
Adequacy of resection in patients undergoing breast conservation.

Breast Conservation Surgery (n = 583)			
Outcome Measure	Localization Technique		P Value
	Ultrasound guided [n = 521] N (%)	Wire localized [n = 62] N (%)	
Margin revision	26 (5.0%)	9 (14.5%)	0.0073
Closest margin of resection in mm median (25th, 75th percentile)	5.0 (2.0, 8.5)	5.0 (2.0, 8.0)	0.6635
Tumor volume in cm3	2.11 (0.38, 5.42)	3.15 (1.17, 5.51)	0.2187
Resection volume in cm3	3.46 (0.61, 8.76)	5.04 (1.87, 8.81)	0.2252

DCIS, often associated with microcalcifications, was more often localized with wire as opposed to ultrasound in our series albeit the difference was not statistically significant when T stages were compared. On post hoc analysis collapsing for Tis versus all other T stages, the p-value for WL versus IOUS guidance was marginally significant in favor of WL [p = 0 0.0772]. Univariate analysis in our series identified in situ disease to be associated with high rate of margin revision, however, this association was not seen in the multivariate model. Ahmed et al. identified a similar trend of heterogeneity of DCIS in a meta-analysis of small cohorts.[31] DCIS was more likely to be localized with a WL as opposed to IOUS but this trend did not reach a significant value [p = 0.65]. Murphy et al. also identified in situ cancer as a risk factor for positive margins but DCIS and localization technique did not converge for the multivariate analysis to identify attributable risk.[32] DCIS has been reported as a risk factor for positive margins,[33] but the only study on IOUS versus WL surgery done exclusively for in situ disease was published by James et al. which concluded similar positive margin rate in both groups (10.4% vs. 11.9%).[34] Despite this dissimilarity between the two groups, the fact that approximately 90% of breast conservation was achievable with IOUS guidance, and that the select high risk group subjected to WL had similar margin re-excision rate compared with more expensive and logistically challenging approaches, must be acknowledged. Interestingly, the difference in margin re-excision after the adoption of consensus guidlines in this series was not significant despite at least 2 mm desirable margin for DCIS.

Palpable, Non palpable, and sonographically invisible lesions: Our series encompasses three types of lesions that were resected with IOUS ultrasound guidance. First, 37% of lesions were clinically palpable. Relying on tactile skills and preoperative imaging for palpation guided resection is problematic, particularly in dense breasts.[13] Up to 40% positive margins are described after palpation guided surgery.[35] In our series, none of the 191 palpable lesions had a margin revision after IOUS guided resection. Excessive volume of resection has also been reported with palpation guided excisions.[36] The COBALT-trial was the first multicenter randomized controlled trial that compared palpation versus ultrasound guided excision of palpable tumors that showed dramatic reduction in positive margin rate in favor of intraoperative ultrasound [3% vs. 17%].[11] Second, for the clinically occult, ultrasound visible cancers, the rate of successful intraoperative ultrasound localization varies between 95% and 100%.[35] In the current series, 24 of 264 (9.0%) non palpable, ultrasound visible lesion resected with IOUS guidance required margin revision. Rahusen et al. reported superiority of IOUS guidance over WL after randomization of 49 patients with non-palpable tumors.[10] A systemic review and meta-analysis comparing IOUS versus WL of clinically occult lesions, reported significant difference between two groups in terms of tumor free margins in favor of IOUS guidance [OR = 0.52; 95% CI: 0.38–0.71].[31] Third, lesions that are clinically occult and are not visible on ultrasound represent 13% (n = 66) of all cancers resected with ultrasound guidance in the current series; 2 of these (3%) needed margin revision. Twenty (30.3%) of these lesions had a sonographically visible clip placed according to radiology reports. However, we have reported before that iatrogenic hematoma created from the biopsy itself is visible on ultrasound for a few weeks post biopsy.[18] It is difficult to distinguish between clip visibility and hematoma that assisted with intraoperative guidance in this series. It is important to note that 30% of all patients in this series had a sonographically visible clip placed according to radiology reports across both groups.

Resection Volume: The secondary goal of breast conservation beyond negative margins is an acceptable cosmetic outcome, which is directly related to volume of resected specimen.[37] Precise localization of tumor should allow for minimal resection of healthy margin keeping the resection volume low. We demonstrated that resection volume is lower with IOUS guidance compared to WL albeit it was not statistically significant. Previously, we have reported smaller resection volume with IOUS guided approach compared to WL (85.0 vs. 142.2 cm^3; p = 0.0041) despite larger tumor size.[17] Snider and Morrison also reported smaller resection volume in IOUS guided lumpectomy (62.6 cm^3) compared to WL lumpectomy (81.1 cm^3) despite twice the tumor size in the former.[9] Intuitively, as the volume of resection decreases while ensuring negative margins with the use of intraoperative ultrasound, cosmetic outcome should be positively affected.

Impact of Consensus Guidelines on Margin Revision: In the current series, the median closest margin and the interquartile range is similar across both groups over a decade. However, the

Table 4
Multivariate binomial logistic regression analysis for rate of margin revision in patients undergoing breast conservation.

Breast Conservation Surgery (n = 583)		
Model	Odds Ratio (95% CI) for margin revision ultrasound-guided [n = 521] versus Wire-localized [n = 62]	P Value
Unadjusted (no covariates)	0.31 (0.14, 0.70)	0.0045
Adjusted for: age at diagnosis, T stage, neoadjuvant chemotherapy, and cancer type	0.25 (0.11, 0.59)	0.0014
Adjusted for: age at diagnosis, T stage, neoadjuvant chemotherapy, cancer type, and tumor volume	0.25 (0.11, 0.58)	0.0013
Adjusted for: age at diagnosis, T stage, neoadjuvant chemotherapy, cancer type, and tumor volume (excluding patients with pathological complete response to neoadjuvant chemotherapy)	0.26 (0.11, 0.60)	0.0016

Table 5
Comparison of other localization techniques (in literature) with ultrasound guided and wire localization resection in the current paper for the rate of margin revision in patients undergoing breast conservation utilizing imaging based selection criteria.

Reported Literature		Margin Revision		Fisher exact p-value for comparison with current study	
Technique	Author	N/Total	Percentage	Ultrasound guided 26/521 (5.0%)	Wire localized 9/62 (14.5%)
Radioactive seed localization	Cox	17/64	26.6	<0.0001	0.1238
	van Riet	15/325	4.6	0.8703	0.0071
	Alderliesten	2/46	4.3	1.0000	0.1121
	McGhan	118/767	15.4	<0.0001	0.8481
Radar localization	Cox	17/101	16.8	<0.0001	0.8266
	Mango	4/54	7.4	0.5132	0.2546
Magnetic seed localization	Lamb	30/137	21.9	<0.0001	0.2528

consensus guidelines for margin revision were published in March of 2014. Prior to these guidelines, our practice was to revise all margins <2 mm on final pathology; this practice was changed to 'no ink on tumor' for invasive cancers since the publication. In our analysis, the impact of this practice change on margin revision revealed that the 2 mm threshold caused stark difference in the rate of margin revision, diminishing significantly after March 2014. Since the 25th centile of closest margin is 2 mm in our series, it suggests that approximately 15 patients had <2 mm closest margin in the WL group. Since the margin revision rate was much higher at 33% in this group before guideline change, we suspect that this is the group that was most impacted by guideline change. This was confirmed by test of significance for effect modification. This suggests that the risk of margin revision with WL in patients with

Table 6
Logistics of lesion localization techniques for breast conservation in current day practice.

Localization Technique	Components	Advantages	Disadvantages
Wire localization	•Wire •Needle delivery system •Imaging approach	• Safe • Effective • Well-established • Inexpensive • Compatible with Mammogram, ultrasound, and MRI	• Same day scheduling issues • External wire vulnerable to transaction, fractures, and displacement • Patient discomfort • Limits incision choices/cosmesis
Radioactive Seed Localization	• Iodine-125 labelled titanium seed implant • Needle delivery system • Gamma probe detector/ion chamber • Imaging approach	• Scheduling flexibility • No external components • No depth limitation • Better cosmetic outcome • No specimen radiograph needed	• Cost • Radiation safety precautions • Radiation exposure to patients and staff • No repositioning once deployed • Not MRI compatible
Radar Localization	• Radar reflector • Needle delivery system • Detector • Console • Imaging approach	• Scheduling flexibility • No external components • No radiation exposure • No radiation safety precautions • Better cosmetic outcome • No specimen radiograph needed	• Cost • Depth limitation • No repositioning once deployed • Not MRI compatible • Interference with halogen lights in OR • Nickel allergy concerns
Magnetic Seed Localization	• Stainless steel seed implant • Needle delivery system • Magnetizing detector probe • Imaging approach	• Scheduling flexibility • No external components • No radiation exposure • No radiation safety precautions • Counts depicts depth • Better cosmetic outcome • No specimen radiograph needed	• Cost • Depth limitation • No repositioning once deployed • Not MRI compatible • Need for non ferromagnetic instruments in OR • MRI artifact
Radiofrequency Identification Tag Localization	• RFID tag • Needle delivery system • Handheld reader device • Imaging approach	• Scheduling flexibility • No external components • Distance gauge for depth • No radiation exposure • No radiation safety precautions • Counts depicts depth • Better cosmetic outcome • No specimen radiograph needed • Could mark tumor margins	• Cost • No repositioning once deployed • Potential concerns with proximity to cardiac pacemakers • Reader responsiveness to metals • Potential for tag migration • MRI artifact
Intraoperative Ultrasound	Ultrasound equipment	• Most patient friendly • No additional procedures after biopsy • Most cost effective • Ability to evaluate all margins intraoperatively • Robust data including randomized trials • Inexpensive • Excellent planning for cosmetic incisions	• Commitment to learning the technique • Targeting hematoma for non visible lesions needs surgical schedule within a few weeks

unfavorable imaging characteristics of extensive microcalcifications is now even lower with this new standard (even though the threshold for margin revision in DCIS remains 2 mm). Therefore, newer technologies have to be considerably better to be superior to WL. Impact of consensus statement on guidelines for margin revision has been reported to drop the odds ratio of margin revision by 35% from 22% before the publication to 14% after the publication.[38] Interestingly, we did not see this trend in the overall data; however, the impact was obvious in the WL group with a drop from 33% to 8.5% before and after the publication. It is plausible that overall data does not show significant change in margin revision rates because 90% of patients were treated with IOUS guidance with a considerably low rate of re-excisions even at baseline before the guidelines changed.

Position of Wire Localization among Newer Techniques: Given that most breast cancers, clinically palpable and occult, are visible on ultrasound, real-time ultrasound imaging should be the gold standard to guide breast conservation. Whereas, this audit is not a randomized comparison of IOUS and WL, it highlights the fact that inherent advantages (cost, comfort, ease of scheduling, and noninvasive nature) of IOUS made this an effective approach in 90% of cases over a decade. Moreover, selection bias for the choice of WL in high risk imaging features for positive margins did not reveal a much higher rate of positive margins in that group compared with new techniques reported in literature. The newer more costly techniques including radioactive seed localization, magnetic seed localization, radar localization, and radiofrequency identification tag localization in unselected patients are comparable to WL in current paper.[39,40] More importantly, all studies documenting the efficacy of these devices have compared them to WL (without assessment of ultrasound visibility) as opposed to the documented best technique, i.e. IOUS. Overall, studies comparing radioactive seed localization to WL report inadequate margins in 7%–30% versus 55–57% respectively; studies on radar localization report 8%–17% reoperation rates.[39] One systemic review reported lower margin revision rates with radioactive seed localization compared to WL; while another review with meta-analysis reported no clear evidence in favor of radioactive seed localization.[41] Similarly magnetic seed localization is associated with 7%–12% margin revision in limited small publications.[42,43] The newest technology being evaluated is radiofrequency identification with very limited results. Pragmatically, if surgeons embraced IOUS guidance for breast conservation for vast majority of their patients, the issue of technical improvement will be pertinent to a small group of cancers associated with extensive microcalcifications requiring bracketing (10% over 10 years). This would be an appropriate group to compare WL with new technologies to elucidate if they offer a cost-effective advantage. Table 6 delineates the logistics associated with these techniques to provide insights into practicality of their utilization in routine practice. Clearly, the use of IOUS is logistically most feasible technique to achieve the goals of breast conservation with no additional patient discomfort. Given the capital and running costs, and other significant drawbacks of the newer techniques, it is prudent to consider feasibility of their adoption compared to IOUS. In fact, IOUS is reported to be even less expensive than WL which itself is much more cost-effective compared to the newer technologies described above.[44]

In summary, our largest series contributes to the ever increasing evidence in support of intraoperative use of ultrasound by breast surgeons. For optimal care of breast cancer patients, the role of adequate training of breast surgeons in ultrasound technique cannot be overlooked. Current status of breast surgical oncology continues to demonstrate a low adoption rate of ultrasound among breast surgeons ranging between 2% and 17% survey responders.[45] This is largely due the fact that both surgical residency programs and breast fellowship programs lack formal structured training in diagnostic and interventional breast ultrasound.[46,47] Since the learning curve for breast ultrasound is small,[45] it is reasonable and important to formalize the theoretical and practical skills teaching to allow trainees the opportunity to master the technique through adequate case load exposure under supervision. This will require serious advocacy and commitment by training programs and experts in the field.

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Declaration of competing interest

None.

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