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ORIGINAL ARTICLE – BREAST ONCOLOGY

Lowering Re-excision Rates After Breast-Conserving Surgery: Unraveling the Intersection Between Surgeon Case Volumes and Techniques

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ABSTRACT

Background. The re-excision rates after breast-conserving surgery (BCS) are significantly varied, with surgeon case volume as one influential factor. Surgeons with higher case volumes have been shown to have lower reoperation rates. This study attempted to determine whether this may be attributable to excessive breast tissue removal during initial BCS.

Methods. A retrospective study analyzed referrals to the authors' cancer center during 3 years. Patients undergoing initial BCS for ductal carcinoma in situ or T1–T3 breast cancers were included. Patient age, tumor factors, surgeon case volume, and the calculated resection ratio (CRR) were analyzed. The total resection volume was divided by the optimal resection volume to produce the CRR, which reflected the magnitude of excess tissue resected during initial BCS. Comparison of the mean CRR between surgeon case-volume categories was performed with a repeated measures analysis of variance. A multivariate regression model assessed the effects of the CRR and surgeon case volume on re-excision rates.

Results. Larger tumor size, lobular histology, and lower CRR were associated with increased re-excision rates. The CRR was similar for each surgeon case-volume group. Surgeon case volume was not independently associated with re-excision rates, but surgeons with very high case volumes had lower odds of re-excision than surgeons with intermediate case volumes (odds ratio 0.44; 95% confidence interval 0.21–0.91).

Conclusions. When control was used for the CRR, apparent differences in re-excision rates between surgeon case-volume groups were observed, suggesting that surgeons with higher case volumes may be more accurate when performing BCS.

Breast-conserving surgery (BCS) is the preferred surgical approach for most patients with early-stage breast cancer. The two primary considerations for surgeons performing BCS are the oncologic safety of the procedure and the cosmetic result. Currently, clear recommendations exist for what constitutes an appropriate margin after BCS.[1,2] However, no minimum acceptable standard exists for patient satisfaction with cosmetic outcome. Reports suggest that 68% to 93% of patients are satisfied with the appearance of their breast after BCS.[3–6]

Several factors are known to be associated with poorer cosmetic result, including patient age, body mass index (BMI),[4,7] breast size, location of tumor,[4] percentage of breast tissue removed,[4,8] volume of tissue removed,[3] and the need for re-excision.[4,9,10] The latter factors are particularly relevant given that they are largely within the surgeon's control. The surgeon performing the operation must delicately balance competing priorities to produce the ideal outcome of clear pathologic margins while minimizing the amount of excess breast tissue removed.[11] Thus, accuracy in performance of BCS is crucial.

Although BCS is appealing to many patients, it bears the potential need for reoperation. Reoperations may worsen the cosmetic result,[4,9,10] increase complication rates[12] and health care costs,[13] and cause undue psychological stress to

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patients. Reoperation rates after BCS are significantly varied, with institutions reporting rates ranging from 10 to 60%,[14] but with larger population-based studies finding slightly more consistent results (17–35%).[15–19]

Although both patient- and disease-related factors influence the need for reoperation, surgeon variability also is a contributing factor.[16,20,21] Several studies have demonstrated that surgeons with higher case volumes have lower reoperation rates.[16,21] The explanation for this finding has not been fully elucidated. With the competing priorities of BCS in mind, we attempted to determine whether lower reoperation rates among surgeons with higher case volumes can simply be attributed to larger volumes of breast tissue removed at the time of the initial BCS. Removal of breast tissue volume equal to that removed by surgeons with lower case volumes would suggest greater accuracy during the procedure. To our knowledge, this is the first study to investigate this.

MATERIALS AND METHODS

Approval from the University of British Columbia Research Ethics Board was obtained for a retrospective chart review of patients referred to BC Cancer SAH-CSI between 1 January 2010 and 31 December 2012. This is the only institution that provides radiation and medical oncology services within our region, serving a patient population of approximately 750,000 patients. Surgical services for these patients are provided by 36 surgeons in nine separate hospitals.

Oncoplastic techniques for reconstruction of the tissue defect were not being used during the time of our study. Previous analysis performed by our group suggested that patient-, disease-, and surgeon-related factors were having an impact on the need for reoperation after BCS.[21] Most notably, findings showed that surgeons with very high case volumes had lower reoperation rates than surgeons with low case volume.[21]

According to our previous study, patients undergoing BCS for either ductal carcinoma in situ or invasive breast cancer (T1–T3, N0–N2) were identified from the Cancer Agency Information System (CAIS).[21] The patient exclusion criteria were consistent with those in our previous report.[21] Patients with an unknown tumor size or an unknown tissue resection volume also were excluded from the analysis.

The factors considered for analysis were patient age, tumor-related factors (size, grade, histology, ER/PR-HER2 status), tissue resection volume, and surgeon annual case volume, classified as either low (1–4 cases/year), medium (5–9 cases/year), high (10–24 cases/year), or very high (> 25 cases/year). This classification categorized two surgeons as having very a high volume, 9 surgeons as having a high volume, 10 surgeons as having an intermediate volume, and 15 surgeons as having a low volume.

Tissue resection volume included the main specimen and any additional tissue specimens removed. If only two dimensions were reported, the third dimension was assumed to be the smaller of the two dimensions, reflecting a broad-based and thin specimen. If only one dimension was documented, the shape of the specimen was used to predict the remaining dimensions (i.e., a 5-cm spherical specimen was recorded as 5 cm × 5 cm × 5 cm, whereas a 5-cm specimen with no additional description was assumed to be a cavity shave, and its dimensions were recorded as 5 cm × 1 cm × 1 cm). The largest diameter of the tumor was used and assumed to be a sphere.

Two different resection volumes were calculated (the total resection volume [TRV] and the optimal resection volume [ORV]), as suggested by the work of Krekel et al.[11] The TRV, representing the actual volume of breast tissue removed, was assumed to be an ellipsoid (Fig. 1a) and was calculated by the formula, $4/3\pi(a{\cdot}b{\cdot}c)$, where a, b, and c represent half of each of the surgical specimen's three dimensions (cm). Although margin re-excisions were uncommon, secondary tissue specimens were identified, and the volume was added to the main specimen to produce a final TRV.

The ORV represents the theoretical ideal volume of tissue removed, assuming the tumor to be spherical in shape and excised with a 1-cm margin of healthy tissue (Fig. 1b). This margin was previously chosen by Krekel et al.[11] based on technical feasibility and acceptable cosmesis. The ORV was calculated by the formula, $4/3\pi(r + 1.0\text{ cm})$,[3] where r represents the tumor radius, which equals half of the tumor diameter (cm).

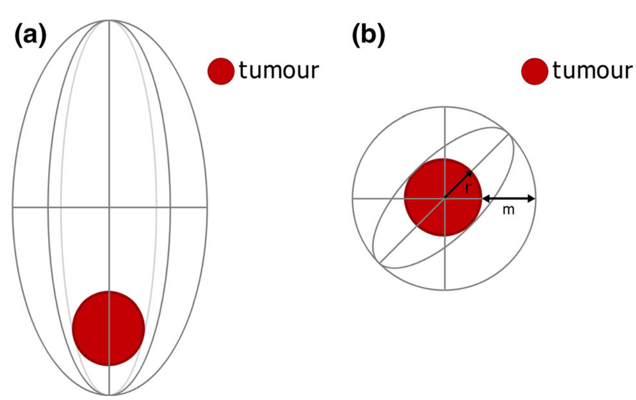

FIG. 1 **a** Visual representation of total resection volume (TRV). **b** Visual representation of optimal resection volume (ORV), where *r* represents the tumor radius and *m* represents a 1-cm margin of healthy breast tissue

Finally, the TRV was divided by the ORV to produce the calculated resection ratio (CRR), which reflected the magnitude of excess breast tissue resected (CRR = TRV/ORV). An ideal excision would have a CRR of 1.0, where the TRV is equal to the ORV. In other words, the tumor would be excised with a 1-cm margin of healthy breast tissue. The CRR was used to represent the tissue resection volume in our analysis for each BCS procedure. A CRR less than 1.0 represented removal of less than 1 cm of tissue around the tumor, and a CRR greater than 1.0 represented removal of more than 1 cm of normal tissue.

Comparison of the CRR between surgeon volume categories was performed using a repeated measures analysis of variance (ANOVA), with surgeon as the repeated subject. For the multivariate analysis, a generalized estimating equation for logistic regression was used, with the patient re-excision as the outcome and the surgeon as the repeated subject. The CRR and surgeon case volume were entered as independent variables (continuous and categorical, respectively) and the model was adjusted for age, tumor size, tumor grade, and tumor histology for assessment of their effect. A Bonferonni correction was used to control for multiple testing when surgeon volume categories were compared after regression analysis.

RESULTS

During a 3-year period, 541 patients underwent attempted BCS, with adequate pathology reports available for 522 of the patients. The median tumor size was 1.7 cm (interquartile range [IQR], 12–25 cm), and the median patient age was 64 years (IQR, 55–71 years). The majority of the cases (82%) involved invasive ductal carcinoma (Table 1). Most of the procedures were performed by surgeons classified as either high (40%) or very high (21.8%) case-volume surgeons. Nearly half (47.5%) of the BCS cases managed had a CRR greater than 3.0, whereas one third of the cases had a CRR greater than 4.0. The CRR and re-excision rate had an inverse relationship.

Surgeons managing more than 25 cases per year had the lowest observed re-excision rate (18.4%). As surgeon case volumes decreased, re-excision rates generally increased, with a re-excision rate of 23.4% for high-volume surgeons, 36.9% for intermediate-volume surgeons, and 34.1% for low-volume surgeons.

The distribution of the CRR was similar for each surgeon-volume category, with low-volume surgeons having a median CRR of 2.8 and very high-volume surgeons having a median CRR of 3.5 (Fig. 2). No evidence was found to suggest that the mean CRR differed among the four surgeon-volume categories ($p = 0.39$).

The regression analysis showed evidence that tumor size, lobular histology, and CRR were associated with re-excision rates after BCS when adjustment of other factors was performed (Table 2). A one-unit change in tumor size (i.e., from 1 to 2 mm) was associated with a slight increase in the need for re-excision (odds ratio [OR] 1.04; 95% confidence interval [CI] 1.02–1.06). Lobular carcinomas had nearly twice the odds of re-excision relative to ductal carcinomas. Furthermore, a one-unit change in the CRR (i.e., a CRR change of 1–2) was associated with decreased odds of re-excision (OR 0.90; 95% CI 0.80–1.00).

The generalized estimating equation logistic regression analysis showed that an incremental increase in re-excision rates was associated with larger tumor sizes (Table 3). A 20-mm tumor was nearly twice as likely to require re-excision as a 5-mm tumor (OR 1.85; 95% CI 1.34–2.55), and a 50-mm tumor was more than six times as likely (OR 6.33; 95% CI 2.42–16.65).

A decreasing need for re-excision was noted as the CRR increased (Table 4). For instance, a BCS procedure with a CRR of 2 was associated with a 10% decrease in odds for needing re-excision compared with a BCS procedure with a CRR of 1 (OR 0.90; 95% CI 0.80–1.00), whereas a CRR of 7 was associated with nearly a 50% decrease in odds for needing re-excision (OR 0.52; 95% CI 0.27–1.00).

Despite a trend suggesting decreased re-excisions among higher-volume surgeons, surgeon case volume was not independently associated with re-excision rates when low-volume surgeons were used as the reference group (Table 2). Because the adjusted re-excision rates were higher for the intermediate-volume surgeons, comparison of individual case-volume groups was performed (Table 5). Evidence showed that very high-volume surgeons had lower odds of re-excision than intermediate-volume surgeons (OR 0.44; 95% CI 0.21–0.91), with a notable difference also found when high-volume surgeons were compared with this group (OR 0.57; 95% CI 0.28–1.12).

DISCUSSION

Efforts are ongoing to improve the care provided to patients with breast cancer. Although oncologic outcomes are of primary importance, interest in survivorship issues is increasing, with significant consideration focused on appearance of the breast after surgical treatment.[22,23] This is particularly relevant for those undergoing BCS. Studies show increasing awareness of cosmetic variability after BCS, as measured by various aesthetic scoring systems and patient-reported outcomes (PROS).[9,24,25] Lower breast satisfaction after BCS has been identified among patients with an elevated BMI,[7,26] higher-stage disease, and low

TABLE 1 Descriptive clinicopathologic, surgeon, and resection volume characteristics as well as unadjusted re-excision rates

Characteristic	Total patients (n = 522)	% Total patients	Observed re-excision rate (%)
Surgeon volume			
Very high	114	21.8	18.4
High	209	40.0	23.4
Intermediate	111	21.3	36.9
Low	88	16.9	34.1
Age (years)			
0–44	20	3.8	35.0
45–54	101	19.3	38.6
55–64	158	30.3	28.5
65–74	152	29.1	24.3
75+	94	17.4	14.3
Tumor size (mm)			
0–9	81	15.5	14.8
10–19	214	41.0	17.3
20–29	128	24.5	25.8
30–39	50	9.6	44.0
40–49	15	2.9	60.0
50+	34	6.5	82.4
Tumor grade			
Low	138	26.4	17.4
Intermediate	222	42.5	29.7
High	162	31.0	31.5
Histology			
Invasive ductal carcinoma	428	82.0	24.8
Invasive lobular carcinoma	43	8.2	41.9
DCIS	51	9.8	33.3
Lymph node status			
N0	349	66.9	26.1
N1	106	20.3	29.2
N2	22	4.2	36.4
NX	45	8.6	24.4
Calculated Resection Ratio (CRR)			
≤ 0.5	40	7.7	75.0
0.5–1	45	8.6	48.9
1–2	100	19.2	29.0
2–3	89	17.0	22.5
3–4	72	13.8	18.1
> 4	176	33.7	15.3
ER status			
Positive	398	76.2	25.4
Negative	55	10.5	30.9
Unknown/borderline	69	13.2	33.3
PR status			
Positive	311	59.6	25.1
Negative	100	19.2	25.0
Unknown/borderline	111	21.3	34.2
HER2 status			
Positive	58	11.1	27.6

TABLE 1 (continued)

Characteristic	Total patients (n = 522)	% Total patients	Observed re-excision rate (%)
Negative	350	67.0	24.3
Unknown/borderline	114	21.8	35.1

DCIS ductal carcinoma in situ, *CRR* calculated resection ratio, *ER* estrogen receptor, *PR* progesterone receptor, *HER2* human epidermal growth factor receptor 2

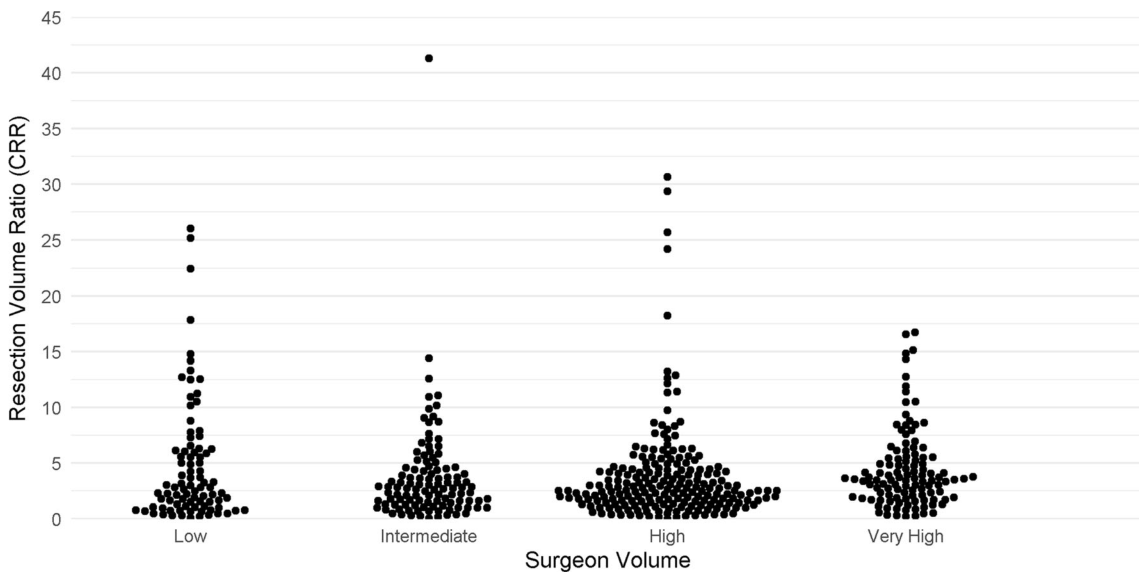

FIG. 2 Beeswarm plot illustrating distribution of the calculated resection ratio (CRR) for each surgeon case-volume category

socioeconomic status, as well as among those treated with chemotherapy or radiation.[27] Although these factors require consideration by the surgeon, they are not modifiable. On the other hand, both volume of breast tissue removed[3,28] and re-excision rates[5,9] also have been associated with cosmetic outcomes after BCS and to a great extent are within the control of the surgeon. The ideal BCS requires a delicate balance of minimizing removal of excess breast tissue to maintain breast appearance and achieving adequate pathologic margins to avoid the need for further surgery.

Reoperation after BCS has been considered for use as a quality metric given the high inter-surgeon variability of this outcome.[16,29] This issue has been addressed by an American Society of Breast Surgeons (ASBrS) consensus conference with a focus on mitigation strategies.[29] We also have previously reported that patients undergoing BCS by very high-volume surgeons are less likely to require a second operation, suggesting a correlation between surgeon case volume and treatment outcome.[21]

Similar to our previous report,[21] we found that increasing tumor size and lobular histology are associated with increased re-excision rates. Overall, surgeon case volumes did not influence re-excision rates (Table 2), but several categories differed notably after control for the effect of the individual surgeon (Table 5). Surgery performed by very high-volume surgeons had lower odds of reoperation than surgery performed by intermediate-volume surgeons (OR 0.44; 95% CI 0.21–0.91). High-volume surgeons manifested lower odds of re-excision than intermediate-volume surgeons, but the difference did not reach statistical significance, potentially because the study was underpowered.

Although pursuit of a low reoperation rate is desirable from both a patient and a health systems perspective,[13] consideration of either perspective in isolation may result in unintended consequences. Some surgeons may be inclined to recommend mastectomies, especially in cases with a higher risk of pathologically positive margins. Alternatively, other surgeons may remove larger areas of normal tissue to minimize the need for reoperation. This latter scenario would have detrimental consequences given the inverse correlation between the volume of breast tissue removed and cosmetic outcomes.[3,28] Although lowering the re-excision rate is desirable, this should not be at the expense of excessive breast tissue removal. We

TABLE 2 Generalized estimating equations (GEE) logistic regression adjusted for patient and tumor factors

Covariate	OR (95% CI)	*p* value
Tumor grade		
Low	Reference	
Intermediate	1.41 (0.76–2.63)	0.28
High	1.04 (0.54–2.00)	0.92
Diagnosis age	0.98 (0.95–1.01)	0.12
Tumor size (mm)	1.04 (1.02–1.06)	0.0002
Histology		
Ductal carcinoma	Reference	
Lobular carcinoma	1.76 (1.03–2.62)	0.04
DCIS	1.62 (0.78–3.34)	0.20
Surgeon volume		
Low	Reference	
Intermediate	1.03 (0.44–2.37)	0.95
High	0.58 (0.24–1.40)	0.22
Very high	0.45 (0.20–1.03)	0.06
CRR	0.90 (0.80–1.00)	0.05

OR odds ratio, *CI* confidence interval, *DCIS* ductal carcinoma in situ, *CRR* calculated resection ratio

TABLE 3 Odds ratio of re-excision based on tumor size

Tumor size (mm)	OR	95% CI
10 versus 5	1.23	1.10–1.37
20 versus 5	1.85	1.34–2.55
30 versus 5	2.79	1.63–4.77
40 versus 5	4.20	1.99–8.91
50 versus 5	6.33	2.42–16.65

OR odds ratio, *CI* confidence interval

TABLE 4 Odds ratio of re-excision based on calculated resection ratio (CRR)

CRR	OR	95% CI
2 versus 1	0.90	0.80–1.00
3 versus 1	0.80	0.64–1.00
4 versus 1	0.72	0.52–1.00
5 versus 1	0.64	0.41–1.00
6 versus 1	0.58	0.33–1.00
7 versus 1	0.52	0.27–1.00
8 versus 1	0.46	0.21–1.00
9 versus 1	0.41	0.17–1.00
10 versus 1	0.37	0.14–1.00

OR odds ratio, *CI* confidence interval

hypothesized that surgeons with higher case volumes are more accurate at performing BCS and achieve lower re-excision rates without removing larger volumes of normal breast tissue.

No guidelines exist for determining the appropriate volume of tissue to be removed grossly in BCS. Considerations by the surgeon include imaging characteristics, estimated tumor size, histology, grade, and tumor markers as well as intraoperative findings. Krekel et al.[11] proposed 1 cm of gross removal for an optimal margin of healthy tissue to ensure complete pathologic clearance. To control for tumor size and allow standardized comparisons, these authors suggested using the CRR to represent the amount of excess breast tissue removed. They found that surgeons removed 2.5 times (median) the ideal resection volume (CRR 0.01–42.9). Furthermore, as the CRR increased, the probability of a positive pathologic margin after BCS decreased. In their cohort, if the CRR was less than 1.0, the probability of a positive margin was 40.9%, whereas a CRR greater than 4.0 was associated with a positive margin in 10.7% of cases. This latter finding suggests that even an excessively large resection margin does not guarantee negative pathologic margins in situations with a tumor eccentrically located in the resection specimen. This implies that accuracy is a key component in the performance of BCS.

We found similar trends in our patients, although our primary outcome was the re-excision rate rather than a positive pathologic margin. The median CRR in our entire cohort was 2.83 (IQR 1.53–4.97), similar to that of Krekel et al.[11] The patients with a CRR of 0.5–1.0 had a re-excision rate of 48.9%, whereas those with a CRR greater than 4.0 had a 15.3% chance of undergoing re-excision (Table 1). Although the metrics of pathologic margin involvement and re-excision are not directly comparable, the studies still show marked similarities between them, suggesting a correlation between the CRR and the probability that patients will undergo further surgery. We found a negative linear relationship between the CRR and the odds of re-excision, suggesting that a larger CRR is more likely to indicate pathologically negative margins (Table 4). However, after control for the volume of tissue removed, higher surgeon case volume still was associated with decreased odds of re-excision (Table 5). This suggests that the lower re-excision rates of very high-volume surgeons are not at the expense of excess breast tissue removal.

The correlation between the individual surgeon, re-excision rates, and volume of tissue resection has recently been reported by Valero et al.[30] These authors found a sixfold difference in re-excision rates among surgeons within the same institution after controlling for patient and disease factors. They found large differences among

TABLE 5 Comparison of re-excision rates by surgeon case volume from multivariate analysis with a Bonferonni correction to control for multiple testing

Surgeon volume	OR	Adjusted lower OR	Adjusted upper OR	Adjusted p value
Very high versus high	0.78	0.38	1.61	1.00
Very high versus intermediate	0.44	0.21	0.91	0.02
Very high versus low	0.45	0.15	1.37	0.35
High versus intermediate	0.57	0.28	1.12	0.17
High versus low	0.58	0.18	1.89	1.00
Intermediate versus low	1.03	0.33	3.18	1.00

OR odds ratio

surgeons in the volume of breast tissue resected, which although not statistically significant, was worthy of further investigation.

Our findings suggest that higher-volume surgeons are more accurate with the technical aspects of the procedure, accounting for all factors known to influence re-excision rates after BCS, including variability among the surgeons themselves. Further investigation with a larger sample of surgeons to clarify this finding would be valuable. Used to control for size of tumor and volume of tissue resected, the CRR may be a valuable tool allowing for comparisons between individual surgeons as well.

This study had some limitations, including the limited number of surgeons, particularly in the very high-volume group ($n = 2$). Furthermore, the low number of cases in certain groups, most notably the low case-volume group of surgeons, may have underpowered the study to detect a difference in odds of re-excision between surgeon case-volume groups. We did not collect or document the presence of coexistent invasive carcinoma and extensive ductal carcinoma in situ, which may lead to a higher incidence of pathologically involved margins and a subsequent need for re-excision. This histopathologic characteristic is unlikely to differ between surgeon case-volume subgroups, but because the study did not account for it, this factor is another potential study limitation. Finally, the performance of a re-excision is a surrogate for pathologic margins at the time of initial surgery, with the latter more truly reflecting the adequacy of surgery. The absence of a consensus margin at that time may have influenced management at a surgeon level.[1,31]

The study had several strengths. The most important strength was the use of the CRR as a method to control for the influence of excision volumes on re-excision rates. This is the first population-based study to control for this variable, which suggests that the correlation between higher surgeon case volume and lower re-excision rate cannot be attributed to larger breast tissue resection volumes. Variability was observed between and within surgeon case-volume groups, suggesting that the CRR may differ significantly at the surgeon level. The CRR may have utility for assessing the individual breast surgeon. Our study, although modest in the absolute number of patients, was a population-based study, which may make it more applicable to community-based centers, where most breast surgery occurs.

CONCLUSIONS

Patients undergoing BCS frequently require revisional surgery to ensure adequate pathologic margin status. Although tumor size is the strongest predictor of the need for re-excision, surgeon case volume and the amount of tissue volume resected (CRR) also influence re-excision rates. When the study controlled for the CRR, apparent differences in re-excision rates were observed between surgeon case volume groups, suggesting that surgeons with higher case volumes may be more accurate in performing BCS. Further study with a larger population is required to validate these findings.

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DISCLOSURE There are no conflicts of interest.

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