Technical factors, surgeon case volume and positive margin rates after breast conservation surgery for early-stage breast cancer

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Background: For patients with breast cancer, a negative surgical margin at first breast-conserving surgery (BCS) minimizes the need for reoperation and likely reduces postoperative anxiety. We assessed technical factors, surgeon and hospital case volume and margin status after BCS in early-stage breast cancer.

Methods: We performed a retrospective cohort study using a regional cancer centre database of patients who underwent BCS for breast cancer from 2000 to 2002. We considered the influence of patient, tumour and technical factors (e.g., size of specimen and preoperative diagnosis of cancer available) and surgeon and hospital case volume on margin status at first and final operation. We performed univariate and multivariate regression analyses.

Results: We reviewed 489 cases. There were no differences in patient or tumour characteristics among the low-, medium- and high-volume surgeon groups. High-volume surgeons were significantly more likely than other surgeons to operate with a confirmed preoperative diagnosis and to resect a larger volume of tissue. In our univariate analysis and at first operation, the rates of positive margins were 16.4%, 32.9% and 29.1% for high-, medium- and low-volume surgeons, respectively ($p = 0.002$). In the multivariate analysis, tumour factors (palpability, size, histology), presence of a confirmed preoperative diagnosis and size of resection specimen significantly predicted negative margins. However, when we controlled for these and other factors, high surgeon volume was not a predictor of negative margins at first surgery (odds ratio 1.8, 95% confidence interval 0.9–3.8, $p = 0.09$). Increased hospital volume was not associated with a lower rate of positive margins at first surgery.

Conclusion: Various tumour and technical factors were associated with negative margins at first BCS, whereas surgeon and hospital volume status were not. Technical steps that are under the control of the operating surgeon are likely effective targets for quality initiatives in breast cancer surgery.

Contexte : Chez les personnes atteintes de cancer du sein, une marge chirurgicale négative au cours de la première chirurgie mammaire conservatrice (CMC) réduit au minimum la nécessité de réopérer et atténue probablement l'anxiété postopératoire. Nous avons évalué des facteurs techniques, le chirurgien et le volume de cas de l'hôpital, ainsi que l'état de la marge après la CMC dans le cas du cancer du sein au stade précoce.

Méthodes : Nous avons effectué une étude de cohorte rétrospective en utilisant la base de données d'un centre régional de cancérologie portant sur des patientes qui ont subi une CMC pour traiter un cancer du sein entre 2000 et 2002. Nous avons tenu compte de l'influence des facteurs liés à la patiente et à la tumeur, des facteurs techniques (p. ex., grosseur du spécimen et diagnostic préopératoire de cancer disponibles), du chirurgien et du volume de cas de l'hôpital sur l'état des marges au cours de la première intervention et de l'intervention finale. Nous avons procédé à des analyses de régression unidimensionnelle et multidimensionnelle.

Résultats : Nous avons analysé 489 cas. Il n'y avait pas de différences au niveau des caractéristiques des patientes et des tumeurs et entre les groupes de chirurgiens traitant un volume faible, moyen et élevé de patientes. Les chirurgiens qui traitaient des volumes élevés de patientes étaient beaucoup plus susceptibles que les autres d'opérer en se basant sur un diagnostic préopératoire confirmé et de réséquer un volume plus important de tissu. Dans notre analyse unidimensionnelle et à la première intervention, les fréquences des marges positives se sont établies à 16,4 %, 32,9 % et 29,1 % chez les chirurgiens qui traitaient des volumes élevés, moyens et faibles respectivement

(p = 0,002). Au cours de l'analyse multidimensionnelle, les facteurs tumoraux (palpabilité, taille, histologie), l'existence d'un diagnostic préopératoire confirmé et la grosseur du spécimen réséqué constituaient des prédicteurs importants de marge négative. Cependant, lorsque nous avons tenu compte de ces facteurs et de certains autres, le volume élevé chez les chirurgiens ne constituait pas un prédicteur de marge négative au cours de la première intervention chirurgicale (rapport de cotes, 1,8; intervalle de confiance à 95 %, 0,9–3,8; p = 0,09). Il n'y avait pas de lien entre le volume plus important de l'hôpital et un taux plus faible de marges positives à la première intervention chirurgicale.

Conclusion : Divers facteurs tumoraux et facteurs techniques ont été associés à des marges négatives à la première CMC, mais non au volume de patientes traitées par le chirurgien et l'hôpital. Les étapes techniques contrôlées par le chirurgien exécutant constituent probablement des cibles efficaces pour des initiatives portant sur la qualité des interventions chirurgicales contre le cancer du sein.

Most early-stage breast cancers are managed with breast-conserving surgery (BCS) followed by radiation therapy. The goal of BCS is to completely remove the identified cancer while preserving adequate breast tissue for an acceptable cosmetic result. The presence of a microscopically clear margin is the most important indicator available to ensure completeness of surgical excision. A positive surgical margin is a major predictor of local recurrence, independent of other tumour factors and adjuvant therapies.[1,2] A positive margin at the first operative procedure often leads to subsequent surgery and likely causes anxiety for patients.

There is a growing body of literature that shows a positive relation between provider volume (either surgeon or hospital) and outcome.[3–6] This has been reported for pancreatic, liver and esophageal cancer.[7–12] Many studies have also examined outcomes in breast cancer surgery. Surgery in specialized or teaching hospitals has been shown to generate improved survival and recurrence rates in some studies.[13–15] Other studies have shown improved outcomes in high-volume hospitals[15–18] or if breast cancer surgery is performed by high-volume surgeons.[17,19–21] But the processes by which increased case volume leads to better outcomes are not clear. Some authors have attributed improved outcomes to more appropriate use of adjuvant therapies (hormonal and chemotherapy) that can occur with high-volume surgeons and at high-volume, specialized centres.[13,14,19,20]

Very few studies have examined specific technical factors and processes of surgery related to outcomes in breast cancer. One such report by Kingsmore and colleagues[21] determined that increased case volume and specialization led to improved recurrence and survival rates. They also found that "adequacy of local and axillary surgery" (i.e., surgical margins free of disease, appropriate use of BCS and axillary staging) was an independent predictor of improved outcomes. Our group has recently identified specific technical factors (e.g., presence of confirmed preoperative diagnosis, cavity margin dissection, specimen orientation labelling and volume of tissue excised) that, if performed, are associated with negative surgical margins at first surgery.[22] The report by Kingsmore and colleagues,[21] as well as our own, did not look at the interplay of case volume and technical factors.

In this study, we assessed how relevant technical factors interact with surgeon and hospital case volume to influence the risk of positive margins after BCS in early-stage breast cancer.

Methods

Data sources

We performed a retrospective cohort analysis of patients with early-stage breast cancer (clinical stage I and II) who underwent BCS for invasive breast carcinoma and who were referred to the Juravinski Cancer Centre in Hamilton, Ontario, for radiation therapy. Radiotherapy is highly regionalized in Ontario. The Juravinski Centre services an area of 1.2 million people and is the only source of radiotherapy in this region. Patients were randomly selected from a database at the cancer centre if their first breast surgery occurred between January 2000 and December 2002. We abstracted relevant data from clinical, pathological and operative reports in the patient charts at the cancer centre.

The study protocol was approved by the research ethics board at Hamilton Health Sciences.

Patient, tumour and technical factors

Patient characteristics included age and presence of obesity. Patients were defined as obese if the recorded body mass index was greater than 30. We excluded patients who underwent initial mastectomy or who had a diagnosis of ductal carcinoma in situ only, recurrent disease or T3/T4 disease. Numerous tumour characteristics were considered including size, histology type, grade, multifocality and estrogen-receptor status. We classified tumours as nonpalpable if a needle localization procedure was required for excision. We considered the preoperative diagnosis to be confirmed if malignant cells were identified by either fine needle aspiration or core biopsy. Tissue was considered a cavity margin if one or more labelled specimens distinct from the main surgical specimen were identified in the pathology report. We used

pathology reports to document specimen orientation labelling. We examined the operative and radiological reports to determine if specimen radiographs were performed and to determine the type of localization wire used for nonpalpable tumours. The volume of lumpectomy specimens was defined as the product of the 3-dimensional lengths of the surgical specimen as documented in the pathology report; patients were divided into 2 groups based on the mean volume (≤ or > 167 cm^3). Surgeons operating at the hospital sites affiliated with McMaster University were categorized as academic surgeons.

Surgeon groups and outcomes

Prior to reviewing any outcomes data, we decided that we would use cut-points to create 3 volume groups with approximately equal numbers of cases in each group. Hospitals with low, medium and high case volumes were similarly determined. A positive margin was defined as microscopically confirmed disease (invasive or in situ) at the inked margin following the first surgical excision. Lobular carcinoma in situ at a margin was not considered a positive margin. We measured the rate of positive margins at the first and final procedure.

Statistical analyses

Our sample size calculation was based on a prevalence of positive margins of 30%.[1,2] Accordingly, we estimated that 329 patients would be required to produce a 95% confidence interval (CI) of 5% with an α of 0.05. We doubled this number for the random selection of cases in anticipation that many cases would not meet our study criteria. Demographic and clinical characteristics were summarized among the surgeon volume groups. We used χ^2 or Fisher exact tests for comparison of categorical variables and positive margin rates, and we used *t* tests or Mann–Whitney *U* tests for continuous variables. We performed univariate analyses to evaluate the effect of patient, tumour, technical and case volume factors on margin status, although only the influence of surgeon volume is shown. Factors or independent variables with a significance level of less than 0.10 in the univariate analysis were included in 2 multivariate logistic regression models. The dependent variables were positive margin at first and final resection, respectively. We considered an α of 0.05 to be statistically significant.

RESULTS

During the study period, 2249 cases seen at the Juravinski Cancer Centre were coded as early-stage breast cancer managed with BCS; we randomly selected and reviewed 664 (27%) of these cases. In all, we excluded 165 because of recurrent disease (n = 5), T3/T4 (n = 9), benign disease (n = 4), missing pathology or surgery data or chart not found (n = 51) and initial mastectomy (n = 96). Accordingly, we reviewed 489 breast cancer cases managed with BCS. These surgeries were performed at 26 different hospitals, 4 of which were labelled as academic. Low-, medium- and high-volume surgeon ranges were 1–8, 9–15 and more than 15 cases, respectively. Overall, cases were performed by 74 surgeons, with a mean of 6.6 cases per surgeon. Seven surgeons were categorized as high volume, 14 as medium and 53 as low volume. The patient and tumour characteristics for low-, medium- and high-volume surgeons are shown in Table 1.

The mean age of the patients was 59 years, and 30% were considered obese. Tumours were nonpalpable in 36% of cases. Most tumours were ductal carcinoma (87%) and estrogen-receptor positive (80%). Thirty percent were T2 lesions (2.1–5.0 cm). Multifocal disease was seen in 8%. Thirty-two percent were node positive, and 9% had no axillary staging done. In the univariate analysis, there was no significant difference in patient or tumour characteristics among the 3 surgeon volume groups.

The technical factors for each surgeon volume group are shown in Table 2. Overall, 32.5% of procedures were performed at academic centres. Only 2% of cases were performed under local anesthetic. A confirmed preoperative diagnosis was made before first surgical procedure in 69% of cases. Cavity margins were excised and specimen orientation labelling sutures were placed in about 50% of cases. Specimen radiographs were performed for 83.2% of the nonpalpable tumours. Most institutions used a flexible localization wire. In the univariate analysis, high-volume surgeons were more likely than other surgeons to have an academic affiliation (p < 0.01). High-volume surgeons operated with a confirmed preoperative diagnosis more frequently than low- or medium-volume surgeons (84% v. 60% and 64% respectively, p < 0.001). They also resected cavity margins more often (p < 0.001) and generated larger surgical specimens (p = 0.051). The use of specimen orientation labelling, specimen radiography and needle type was not different among the surgeon case volume groups.

The rate of positive margins and surgeon case volumes are shown in Table 3. There were 127 patients with a positive margin after the first surgery (26%). High-volume surgeons had a lower positive margin rate than low- or medium-volume surgeons (16.4% v. 29.1% and 32.9%, respectively; p = 0.002). The positive margin rate at academic and community hospitals was 24% and 27%, respectively (p = 0.51; data not shown). Of the 489 cases, 128 (26%) patients had a second operation, including 107 of the 127 patients with a positive margin at initial surgery. Twenty patients with initial positive margins did not undergo further surgery. High-volume surgeons had significantly lower reoperation rates (p = 0.004). Four patients had a third operation. Of the reresections, 36 were ultimately mastectomies (7% of the total sample). When re-excision or completion

mastectomy was performed, residual cancer (invasive or in situ) was found in 47% of cases. The final positive margin rate was 5.6%, and this was similar among the surgeon and hospital volume groups. The mean number of operations per patient was 1.27. Rates of positive margins were 22.8% and 27.7% for palpable and nonpalpable tumours, respectively ($p = 0.18$).

Tumour factors such as size, multifocality, histology, palpability, extensive intraductal component and lymphovascular invasion were significant predictors of negative margins at first surgery (Table 4). This is consistent with known predictors of margin status.[1,2,22] Furthermore, a confirmed preoperative diagnosis and more extensive surgical resection (cavity margin dissection and volume of tissue excised) also predicted clear margins at first surgery. On multivariate assessment, high versus low surgeon volume did not predict negative margin status at first surgery (odds ratio 1.80, 95% CI 0.9–3.8, $p = 0.09$) Hospital volume status did not predict margin status at initial and final surgery in both univariate and multivariate analyses (data not shown).

Discussion

Numerous studies have consistently shown that a positive surgical margin is an independent predictor of local recurrence and can lead to further surgery with associated morbidity and patient anxiety.[1,2] We performed this study to assess the relations among technical breast surgery factors, surgeon or hospital case volume and positive margins at first or final surgery in women with early-stage breast cancer treated with BCS. In this study, the overall positive margin rate following first resection was 26%, which is similar to other retrospective series of patients with early-stage breast cancer seen at referral centres.[1,2,23,24,25] The final positive margin rate was 5.6%. In the univariate analysis,

Table 1. Patient and disease characteristics and surgeon volume status

Characteristic	Group, no. (%)				*p* value
	Low volume (1–8 cases)	Medium volume (9–15 cases)	High volume (> 15 cases)	Total	
Surgeons	53 (71.6)	14 (18.9)	7 (9.5)	74 (100)	
Sample size	172 (35.2)	152 (31.1)	165 (33.7)	489 (100)	
Age, yr					0.27
≤ 50	41 (23.8)	37 (24.3)	51 (30.9)	129 (26.4)	
≥ 51	131 (76.2)	115 (75.7)	114 (69.1)	360 (73.6)	
Obesity					0.21
Yes	51 (30.5)	37 (25.2)	54 (34.4)	142 (30.1)	
No	116 (69.5)	110 (74.8)	103 (65.6)	329 (69.9)	
Type of lesion					0.26
Palpable	117 (68.0)	97 (63.8)	98 (59.4)	312 (63.8)	
Nonpalpable	55 (32.0)	55 (36.2)	67 (40.6)	177 (36.2)	
Histologic type					0.57
Ductal	143 (86.1)	132 (89.8)	135 (86.5)	410 (87.4)	
Lobular	23 (13.9)	15 (10.2)	21 (13.5)	59 (12.6)	
Tumour grade					0.28
I	45 (26.3)	43 (28.3)	58 (35.8)	146 (30.1)	
II	72 (42.1)	69 (45.4)	65 (40.1)	206 (42.5)	
III	54 (31.6)	40 (26.3)	39 (24.1)	133 (27.4)	
Tumour size					
T1a/b	37 (21.5)	33 (21.7)	39 (23.6)	109 (22.3)	0.91
T1c	79 (45.9)	76 (50.0)	77 (46.7)	232 (47.4)	
T2	56 (32.6)	43 (28.3)	49 (29.7)	148 (30.3)	
Multifocal disease					0.86
Present	13 (7.6)	14 (9.3)	14 (8.5)	41 (8.4)	
Absent	159 (92.4)	137 (90.7)	151 (91.5)	447 (91.6)	
Extensive intraductal component					0.92
Present	24 (14.2)	19 (12.8)	23 (14.1)	66 (13.7)	
Absent	145 (85.8)	130 (87.2)	140 (85.9)	415 (86.3)	
Estrogen receptor status					0.18
Positive	130 (76.5)	127 (84.7)	133 (81.1)	390 (80.6)	
Negative	40 (23.5)	23 (15.3)	31 (18.9)	94 (19.4)	
Lymphovascular invasion					0.08
Present	29 (17.8)	37 (25.2)	24 (15.4)	90 (19.3)	
Absent	134 (82.2)	110 (74.8)	132 (84.6)	376 (80.7)	

high-volume surgeons generated significantly fewer positive margins at first surgery than low- or medium-volume surgeons. However, when we controlled for tumour and technical factors, high-volume surgeons did not have a significantly lower rate of positive margins at first surgery.

We also found that high-volume surgeons manage breast cancer differently than other surgeons, with significantly higher rates of confirmed preoperative diagnosis, larger surgical specimens and more frequent resection of separate cavity margins, and that these technical factors predicted negative margins at first surgery, even in the multivariate analyses. When a positive margin was reported, further surgical management was similar in all surgeon-volume groups. Hospital case volume was not related to margin status.

Table 2. Technical and surgical factors and surgeon volume status

Variable	Group, no. (%)* Low volume (1–8 cases)	Medium volume (9–15 cases)	High volume (> 15 cases)	Total	*p* value
Surgeons	53 (71.6)	14 (18.9)	7 (9.5)	74 (100)	
Sample size	172 (35.2)	152 (31.1)	165 (33.7)	489 (100)	
Type of hospital					< 0.001†
Community	141 (82.0)	107 (70.4)	82 (49.7)	330 (67.5)	
Academic	31 (18.0)	45 (29.6)	83 (50.3)	159 (32.5)	
Type of anesthetic					0.27
Local	5 (2.9)	4 (2.7)	1 (0.6)	10 (2.1)	
General	166 (97.1)	146 (97.3)	164 (99.4)	476 (97.9)	
Preoperative diagnosis					< 0.001†
Present	102 (60.0)	97 (64.2)	133 (84.2)	332 (69.3)	
Absent	68 (40.0)	54 (35.8)	25 (15.8)	147 (30.7)	
Cavity margins					< 0.001†
Dissected	57 (33.5)	66 (44.0)	94 (57.0)	217 (44.7)	
Not dissected	113 (66.5)	84 (56.0)	71 (43.0)	268 (55.3)	
Specimen orientation labelling					0.28
Present	89 (52.7)	74 (49.3)	96 (58.2)	259 (53.5)	
Absent	80 (47.3)	76 (50.7)	69 (41.8)	225 (46.5)	
Specimen radiograph (nonpalpable cases only)					0.46
Present	45 (88.2)	38 (79.2)	46 (82.1)	129 (83.2)	
Absent	6 (11.8)	10 (20.8)	10 (17.9)	26 (16.8)	
Type of needle for localization for nonpalpable tumours					0.08
Flexible	29 (58.0)	41 (74.5)	32 (55.2)	102 (62.6)	
Rigid	21 (42.0)	14 (25.5)	26 (44.8)	61 (37.4)	
Volume of tissue excised, mean (SD)	158.9 (129)	152.4 (141)	188.6 (133)	167 (135)	0.05

SD = standard deviation.
*Unless otherwise indicated.
†Significant at $p < 0.01$.

Table 3. Surgical margin status and surgeon volume status

Status	Group, no. (%)* Low volume (1–8 cases)	Medium volume (9–15 cases)	High volume (> 15 cases)	Total	*p* value
Sample size	172 (35.2)	152 (31.1)	165 (33.7)	489 (100)	
Positive margins after first resection	50 (29.1)	50 (32.9)	27 (16.4)	127 (26.0)	0.002†
Positive margins after final surgery	11 (6.4)	7 (4.6)	8 (4.8)	26 (5.3)	0.73
Further surgery required, all cases*	51 (29.7)	49 (32.3)	28 (17.0)	128 (26.2)	0.004†
Type of further surgery (for positive margins only)					
Re-excision of margins	29 (70.7)	33 (75.0)	14 (66.7)	76 (71.7)	0.75
Mastectomy	12 (29.3)	11 (25.0)	7 (33.3)	30 (28.3)	

*Includes 107 patients with initial positive margins and 21 patients with initial negative margins.
†Significant at $p < 0.01$.

A positive relation between case volume and outcomes has been identified in various surgical oncology procedures. Most volume–outcome studies are performed using large population-based, administrative databases. However, although such studies are helpful in examining major outcomes such as survival, the data that are available for analysis can be limited. Also, to determine which factors may be causative of a certain outcome, specific patient, tumour and technical factors that are not available in administrative databases may need to be examined. In this retrospective cohort analysis, we looked at specific patient, tumour and surgical factors, as well as margin status, compared with surgeon and hospital case volume. The patient and tumour characteristics in our sample are consistent with other series examining early-stage breast cancer.[17,19,23,24,25] The primary outcome (margin status) is a clinically relevant end point that is often considered to be a quality indicator in breast cancer surgery.[1,26]

In our univariate analysis, we found that high-volume surgeons generated significantly fewer positive margins following first resection. Margin status is an ideal outcome measure for examining a possible volume–outcome relation because the underlying disease characteristics that affect margin status are very well studied and because surgeons have direct influence on the processes of surgery (e.g., preoperative diagnosis, volume of resection, cavity margin excision) that can influence margin status. But it may also suggest that low- or medium-volume surgeons can generate similar clear margins if appropriate pre- and intraoperative processes are followed. Of note, when a positive margin was generated after initial surgery, there was no difference in reoperation rates or type of surgery (re-excision or mastectomy) among the volume groups. Hospital case volume was not associated with margin status, supporting the importance of surgeon and technical factors under the surgeon's control to ensure adequate surgical resection. We did not assess the influence that surgeon and hospital case volumes have on other clinical end points such as local or distant recurrence and survival.

Table 4. Predictors of negative margins from multivariate binary logistic regression*

Variable	Odds ratio (95% CI)	*p* value
Palpable lesion	2.4 (1.2–4.5)	0.007
Ductal histology	2.6 (1.1–5.8)	0.022
Tumour grade	1.1 (0.7–1.7)	0.57
Tumour size T1a/b	1.6 (1.0–2.5)	0.031
Absence of multifocal disease	6.6 (2.4–17.8)	< 0.001
Absence of extensive intraductal component	2.2 (1.0–4.5)	0.032
Absence of lymphovascular invasion	2.1 (1.1–4.3)	0.032
Presence of preoperative diagnosis	2.4 (1.3–4.1)	0.003
Presence of cavity margin	2.2 (1.2–4.0)	0.008
Volume of tissue excised of > 167 cm^3	2.4 (1.3–4.4)	0.005
Surgeon volume		
Low		0.14
Medium	0.9 (0.5–1.6)	0.75
High	1.8 (0.9–3.8)	0.09

CI = confidence interval.
*Hosmer and Lemeshow test of significance = 0.626

Factors that affect outcomes have been extensively reported. Breast cancer surgery in specialized, teaching and high-volume hospitals has been reported to generate improved long-term survival and lower recurrence rates.[13–17] Surgery performed by high-volume surgeons has also been shown to lead to improved survival and lower recurrence rates.[17,19] Authors often attribute such improved outcomes to multidisciplinary care that leads to better care, such as increased use of adjuvant therapies. Some authors suggest that the role of the surgeon may be more specific. Golledge and colleagues[14] have postulated that surgical technique, especially clear margins, may lead to better long-term outcomes. Kingsmore and colleagues[21] determined that an "adequate" surgical resection (including clear margins) was more frequently performed by specialist surgeons. Using logistic regression, they also determined that "adequacy of local surgery" was an independent predictor of improved survival and recurrence rates. Margin status specifically has not been extensively studied.

Specific surgical factors and their relation to surgeon case volume were also examined in our study. There were significant differences in technical factors between high- and low-volume surgeons. High-volume surgeons had a confirmed preoperative diagnosis significantly more often than low-volume surgeons, a practice associated with fewer positive margins. High-volume surgeons removed larger main specimens and more frequently took separate cavity margins. Intuitively, removing more breast tissue would lead to fewer positive margins, and this is consistent with previous reports.[1,27–29] Routine and selective resection of cavity margins has also been shown to decrease the rate of positive margins.[30,31] This study also confirmed the value of obtaining a confirmed preoperative diagnosis.[32,33]

In our study, two-thirds of cancers were managed by low- or medium-volume surgeons. Similar distributions are seen in other geographic areas.[17,34,35] For example, in recent reports of large databases in the United States, 50%–60% of cases are managed by low-volume surgeons.[17,34,35] Thus, it would be difficult to justify the regionalization of breast cancer surgery to high-volume providers given the considerable logistical hurdles needed for this and our multivariate findings that provider volume did not predict margin status at final surgery. It would likely be more efficient to engage surgeon groups and ensure that optimal process-of-care steps are consistently followed, such as the technical steps identified in this analyses that predicted positive outcomes.

There are potential limitations to this study. We identified cases from the database of a regional cancer centre. Accordingly, there may be inherent bias of cases not referred for consideration for adjuvant therapies. Most importantly, we performed a retrospective chart review,

which can make the collection and interpretation of data from operative, radiological and pathology reports problematic (e.g., missing or unreported information). Finally, there was a trend for lower rates of positive margins at first surgery among high-volume surgeons. This may be because of the small sample size. However, our analyses were set a priori. As well, we suggest that it is more likely that surgeon volume does not influence the rate of clear surgical margins at first surgery if appropriate pre- and intraoperative processes are followed. Moreover, high surgeon volume did not correlate with final surgery margin status, even in univariate analyses, nor did hospital volume correlate with first or final margin status. Ideally, these results should be confirmed in a larger, population-based study of quality indicators, outcome and case volume providers.

In this study, high-volume surgeons more frequently attained clear margins. However, in the multivariate analysis, high-volume surgeon or high-volume hospital status did not predict clear margins after initial BCS or after final breast resection. Importantly, technical factors under the surgeon's control such as preoperative diagnosis, cavity margins and the resection of a greater volume of tissue did predict for negative margins at first surgery. Our results highlight the need for education and dissemination of optimal surgical standards to all surgeons, regardless of practice volume or teaching status. Regionalization of breast surgery to high-volume surgeons or hospitals may not be needed if such standards are consistently met.

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