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Prevalence and consequences of axillary lymph node dissection in the era of sentinel lymph node biopsy for breast cancer

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Abstract

Background—Despite clear guidelines for its use and wide adoption, no population-based study has examined the extent to which patients with early stage breast cancer are benefiting from sentinel lymph node biopsy (SLNB) by being spared a potentially avoidable axillary lymph node dissection (ALND) and its associated morbidity.

Objective—Examine variation in type of axillary surgery performed by surgeon volume; investigate the extent and consequences of potentially avoidable ALND.

Research design/subjects—Observational study of older women with pathologically node-negative Stage I–II invasive breast cancer who underwent surgery in a SEER state in 2008–2009.

Measures—Surgeon annual volume of breast cancer cases and type of axillary surgery were determined by Medicare claims. An estimated probability of excess lymphedema due to ALND was calculated.

Results—Among 7,686 pathologically node-negative women, 49% underwent ALND (either initially or after SLNB) and 25% were operated on by low volume surgeons. Even after adjusting for demographic and tumor characteristics, women treated by higher volume surgeons were less likely to undergo ALND (medium volume: OR 0.69 [95% CI 0.51–0.82]; high volume: OR 0.59 [95% CI 0.45 – 0.76]). Potentially avoidable ALND cases were estimated to represent 21% of all expected lymphedema cases.

Conclusions—In this pathologically node-negative population-based breast cancer cohort, only half underwent solely SLNB. Patients treated by low volume surgeons were more likely to undergo ALND. Resources and guidelines on the appropriate training and competency of surgeons to assure the optimal performance of SLNB should be considered to decrease rates of potentially avoidable ALND and lymphedema.

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Keywords

breast cancer; axillary surgery; surgeon volume; surgeon specialty; surgical oncologist; sentinel lymph node biopsy; axillary lymph node dissection

INTRODUCTION

Sentinel lymph node biopsy (SLNB) is the standard of care for axillary staging in early stage, clinically node-negative breast cancer.[1–3] Randomized controlled trials have demonstrated that patients undergoing SLNB, compared to axillary lymph node dissection (ALND), have similar disease-free survival but lower incidence of lymphedema and other arm/shoulder morbidity which are associated with decreased quality of life and increased costs.[4–10] One recommendation on the American College of Surgeons *Choosing Wisely®* list is to not perform ALND on patients with clinically node-negative stage I–II breast cancer without attempting SLNB.[11]

Despite these findings and recommendations supporting the use of SLNB, it remains unclear whether this major advance is improving the outcomes of the large majority of women with early stage breast cancer who are treated in the community by surgeons who perform relatively few breast cancer operations.[12,13] Importantly, there is a learning curve to accurately perform SLNB.[14–18] Proponents, including the American Society of Breast Surgeons, advocated in the earlier years of SLNB that surgeons needed to perform 20–30 SLNBs with completion ALND to achieve high accuracy rates.[16,19,20] Recent studies have demonstrated that women are more likely to undergo SLNB if they are treated by surgeons who specialize or focus in breast cancer, defined by volume or percentage of breast cancer cases and membership in breast and surgical oncology societies.[21–23]

In the SLNB era, reasons why a woman may undergo ALND include: preoperative evidence of lymph node involvement; preoperative clinical, radiographic and/or intraoperative concern for metastasis; SLNB reveals metastasis; attempted but failed SLNB; SLNB not offered by surgeon; SLNB not available at treating facility. Surgeons with less experience and expertise with SLNB may be less likely to offer SLNB, more likely to not identify sentinel nodes, and more likely to perform ALND after a negative SLNB if there is intraoperative concern whether the sentinel node was accurately identified and/or if any axillary (sentinel and/or non-sentinel) nodes are grossly concerning for metastasis.

Although the efficacy of SLNB has been established in clinical trials and SLNB was adopted into clinical practice by the mid-2000s,[24,25] no population-based effectiveness study has determined the extent to which early stage breast cancer patients are benefiting from SLNB by being spared a potentially avoidable ALND, thereby avoiding a higher risk of lymphedema. This study, performed in a pathologically node-negative population-based cohort, addresses this gap in knowledge by examining variation in type of axillary surgery by surgeon volume, and investigating the prevalence and consequences of ALNDs with a special focus on excess lymphedema.

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METHODS

Study Cohort and Data Sources

Data are from the National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER)-Medicare linked data set.[26] The cohort consisted of women 66–90 years of age at the time of diagnosis of an initial incident, unilateral, pathologic T1/T2N0M0 invasive ductal, lobular or mixed ductal/lobular breast cancer from January 1, 2008 through December 31, 2009 who underwent breast and axillary surgery in a SEER state and had at least one lymph node removed. We focus on pathologically node-negative women as these are the cases that could have potentially avoided an ALND as none had any positive axillary lymph nodes (sentinel or non-sentinel) removed. Women had to be enrolled in Medicare Parts A and B for at least 12 months before and 12 months after the breast cancer diagnosis (or until death if died less than 12 months after diagnosis). Women were excluded if they were enrolled in a health maintenance organization (because of incomplete claims information), had locally advanced or inflammatory tumors (pT3/T4N0M0), had an unknown number of lymph nodes removed (n=56) and/or underwent neoadjuvant chemotherapy as a complete pathologic response after neoadjuvant chemotherapy might be incorrectly classified as a potentially avoidable ALND.

Lastly, cases had to have an identifiable surgeon by claims who only operated in one of the 10 state-wide SEER registries and performed at least one breast surgery. Surgeons who performed cases in non-SEER states and those that operated in the Detroit and Seattle-Puget Sound SEER registries, and their respective patients, were excluded to avoid potential misrepresentation of surgeon volume because operations performed outside of SEER states and non-SEER regions in Michigan and Washington states were not captured.

Outcome Variables

Type of axillary surgery performed was not available through SEER.[27] As a result, after reviewing the existing literature, our own prior work, and coding manuals, the type of axillary surgery (SLNB only, SLNB followed by ALND, ALND only) was defined based on Medicare claims.[23,28–34] ALND was defined as the presence of any one of 18 lymphadenectomy codes (Current Procedural Terminology [CPT] 19162, 19200, 19220, 19240, 19302, 19305, 19306, 19307, 38740, 38745; International Classification of Disease, 9th revision [ICD-9] 40.3, 40.5, 40.51, 85.43, 85.45–85.48). SLNB was defined as the presence of at least one of 8 codes related to radioactive dye (Healthcare Common Procedure Coding System [HCPCS] A9520, A9541); injection for lymphangiography (CPT 38790, 38792); lymphatic/lymph node imaging (CPT 78195); or axillary lymph node excisional biopsy (CPT 38500, 38525, ICD-9 40.23). Patients who had claims on the same or different days for both SLNB and ALND were classified as starting with SLNB and converting to ALND. A potentially avoidable ALND was defined as either an initial ALND or initial SLNB that converted to ALND because there would not have been any indication for ALND based on pathologically node-negative status.

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Other Variables

Patient age and race were determined from Medicare files. Comorbidity was determined from the inpatient, outpatient and carrier Medicare data for the year preceding the incident breast cancer diagnosis using Klabunde's algorithm.[35] Tumor characteristics (size, grade, lymph node status, number of lymph nodes removed, number of positive lymph nodes, tumor stage) were determined from the SEER registry. Treatment variables were defined by Medicare claims and included type of definitive/final breast surgery and receipt of radiation therapy, chemotherapy and hormonal therapy within 12 months of definitive breast surgery.

Surgeon volume was determined from all SEER state-Medicare breast cancer cases who met the above inclusion criteria, regardless of stage and receipt of neoadjuvant chemotherapy. Based on this larger cohort of about 23,000 cases, the annual number of breast cancer cases was calculated for each surgeon for each year and averaged over the two-year period. After examining the distribution of surgeon case volume, surgeons were classified into one of three groups (low, medium and high) each year, with roughly one-third of cases at the patient level in each volume group. Low volume surgeons were defined as those performing 5 or fewer SEER-Medicare breast cancer cases annually, which corresponds to about <13 breast cancer cases of all ages annually. High volume surgeons were defined as performing more than 15 cases annually (corresponding to about >37 cases of all ages annually), representing at least a tripling of cases compared to the low volume cut-off. These cut-offs are similar to thresholds used in prior breast cancer studies.[36–38]

Statistical Analysis

To predict the likelihood of undergoing an ALND by surgeon volume, a logistic regression model at the patient level with physician-specific random effects was estimated. The model included surgeon volume plus several categorical covariates (age, race, comorbidity, SEER state, tumor size, grade and hormone receptor status) that could affect the type of axillary surgery performed. Missing tumor variable information was treated as a separate category. Estimates were calculated using the GLIMMIX procedure in SAS statistical software (Version 9.3, SAS Institute; Cary, NC).

Estimated probabilities of lymphedema were determined empirically from a comparable Medicare cohort (pathologically node-negative and had at least one lymph node removed) that was prospectively followed for the development of lymphedema;[39] the 5-year actual rates of lymphedema were 9.5%, 22.5%, 34.5% and 40.6% when 1–5, 6–10, 11–15, and 16 or more lymph nodes were removed, respectively. For this study, since actual rates of lymphedema are not known, we assigned each patient a 5-year estimated probability of lymphedema based on the number of lymph nodes removed in SEER and above rates of lymphedema. For each of the three axillary surgery groups and total cohort, the number of estimated lymphedema patients was determined. For the SLNB to ALND conversion group, ALND only group and total cohort, the excess lymphedema probability (lymphedema probability minus lymphedema probability of SLNB group), and number of estimated excess lymphedema patients were calculated.

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RESULTS

The study cohort consists of 7,686 women with pathologically node-negative Stage I–II invasive breast cancer who underwent incident breast cancer surgery between January 1, 2008 and December 31, 2009. Table 1 summarizes the patient and tumor characteristics of the cohort. The mean age at cancer diagnosis was 74.9 years (SD 6.1); most were white and over half had no comorbidities. The majority had tumors that were hormone receptor-positive (83%) and Stage I (80%). Two-thirds underwent breast-conserving surgery, 60% received radiation, 13% underwent chemotherapy and two-thirds received hormonal therapy.

Overall, 1,759 surgeons treated the study cohort. The overall mean annual number of SEER state-Medicare breast cancer cases per surgeon was 6.0 (SD 7.0; range 0.25 – 74). The majority (63%) of surgeons were classified as low volume; 28% were medium volume and 8% were high volume. Mean annual volume of SEER-Medicare breast cancer cases was 1.9 (SD 1.2), 5.9 (SD 3.0) and 17.9 (SD 8.4) for low, medium and high volume surgeons, respectively.

Surgeon volume and ALND

Among the 7,686 women with pathologically node-negative breast cancer, 51% (n=3,889) underwent SLNB only and 49% (n=3,797) underwent a potentially avoidable ALND (Table 1). Among those undergoing ALND, 79% (n=3,015) initially started with SLNB and converted to ALND while the remaining 782 underwent only ALND. Compared to those undergoing SLNB only, women who underwent an ALND were slightly older, had more comorbidities, and had tumors that were larger, high grade, Stage II and less likely to be hormone receptor-positive.

Overall, 25%, 42% and 33% of women were treated by low, medium and high volume surgeons, respectively. In unadjusted analyses, women undergoing ALND were less likely to be operated on by higher volume surgeons. Table 2 displays the results of the multiple logistic regression model with physician-specific random effects, controlling for possible confounders. Women with larger tumors and those with unknown hormone receptor status were more likely to undergo ALND. Compared to patients operated on by low volume surgeons, those operated on by high and medium volume surgeons were less likely to undergo ALND.

Excess lymphedema rates

The mean number of nodes removed in the SLNB only, SLNB converted to ALND and ALND only groups was 2.8 (SD 2.5), 4.4 (SD 4.5) and 11.7 (SD 6.8), respectively (Table 3). The estimated 5-year lymphedema probability rates were 11.0%, 14.1% and 28.2% for women undergoing SLNB only, SLNB converted to ALND, and ALND only, respectively, resulting in an overall 5-year lymphedema probability rate of 13.9% (1,068 patients) for the entire cohort. We considered the baseline probability of lymphedema as 11.0%, as it corresponds to the probability of lymphedema among women undergoing SLNB only in this study cohort. Therefore, estimated excess lymphedema probabilities were 3.1% (93 patients) and 17.2% (135 patients) in the conversion group and ALND only group, respectively. For

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the entire cohort, the number of estimated lymphedema cases was 1,068. If we assume that all patients were legitimate candidates to undergo SLNB only, we would expect 845 cases of lymphedema (7,686 × 0.11). Under this assumption, we estimate an excess of 223 cases of lymphedema, which accounts for 21% (223/1068) of all expected lymphedema cases. Since SEER registries cover about 28% of the US population, we conservatively estimate approximately 3,814 (1,068/0.28) potential cases of lymphedema of which approximately 796 (223/0.28) lymphedema cases in a nationwide Medicare cohort would have been potentially avoidable.

DISCUSSION

In this contemporary, population-based cohort of nearly 7,700 women with stage I–II pathologically node-negative breast cancer, the vast majority (89%) underwent an initial SLNB. However, since 44% converted to ALND and 10% underwent initial ALND, ultimately 51% underwent SLNB only and 49% underwent an ALND. Compared to low volume surgeons, patients treated by higher volume surgeons were significantly less likely to undergo an ALND. We estimate that these potentially avoidable ALND cases represent 21% of all expected lymphedema cases.

Although guidelines from the National Comprehensive Cancer Network and American Society of Clinical Oncology included SLNB as an alternative to ALND for early stage breast cancer as early as the late 1990s and early 2000s and prior studies report on the adoption of SLNB by the mid-2000s,[24,25,40,41] our findings suggest only partial adoption of performing only SLNB in the community by even the late 2000s. As a result, half of these pathologically node-negative patients are undergoing potentially avoidable ALNDs and therefore subjected to an avoidable excess risk of lymphedema. These findings are particularly relevant as the indications to perform only SLNB, and not proceed to completion ALND, particularly in the setting of minimal axillary disease, will likely continue to expand.[1,42] The observed overuse of ALND in elderly women is especially troublesome since national guidelines[2] consider axillary staging (SLNB or ALND) as optional in patients who have particularly favorable tumors, those for whom selection of adjuvant systemic treatment will not be affected by the results, and those with serious comorbid conditions, criteria that are commonly present in elderly women.

To our knowledge, this is the first population-based study of pathologically node-negative patients to examine rates of ALND and to report these patients are less likely to undergo ALND (either initially or after SLNB) if cared for by a surgeon with a higher volume of breast cancer cases. Our findings add to the growing body of literature that demonstrate women with breast cancer are more likely to undergo SLNB if they are cared for by surgeons who specialize in breast cancer care, defined as performing higher volume or percentage of breast cancer cases or holding membership in breast and surgical oncology societies.[21–23] Hospitals, particularly lower volume hospitals, should carefully consider these qualifications when hiring surgeons to ensure high quality breast cancer surgical care.

Our definition of SLNB, similar to prior studies,[31–34] was based on procedural claims related to lymphangiography, lymphatic/lymph node mapping or axillary lymph node

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excisional biopsy because the type of axillary surgery performed was not available in SEER[27] and this cohort underwent surgery prior to 2011, when a CPT code specific to the performance of SLNB (38900) became available. Although Medicare billing claims are generally accurate for breast cancer surgical billing codes,[32,43,44] it is possible that misclassification of the type of axillary surgery performed occurred. In particular, since 39% of patients had claims for both SLNB and ALND and since this SLNB to ALND conversion group had fewer nodes removed than the ALND only group, it is possible that this conversion group is contaminated with some patients who underwent only SLNB. However, if the number of nodes removed is correctly reported in SEER, our reported rates of excess lymphedema are accurate and represent the most conservative estimates. To address the issue of possible contamination, a sensitivity analysis was performed among the SLNB to ALND conversion group where patients were apportioned to either SLNB or ALND based on the conditional probability of undergoing either axillary surgery given the number of nodes removed. The risk of lymphedema in the conversion group was estimated to be 16.5% after reapportioning patients to SLNB or ALND. If the conversion group were contaminated with patients who only underwent SLNB, we would expect to find a lower (not higher) rate of lymphedema in this sensitivity analysis, compared to our reported finding of 14.1%. Another possibility for the relatively low number of nodes removed in the conversion group (compared to the ALND only group) is that this conversion group underwent random "axillary sampling" in addition to SLNB, although there is no data to support such an approach.

A limitation of this study is that the SEER registry does not provide clinical stage information for cases that have pathological stage information; therefore, we could not restrict our study to a clinically *and* pathologically node-negative cohort. We would argue, however, that a pathologically node-negative cohort is the most appropriate from the patient perspective, as those who underwent an ALND (albeit retrospectively) were subjected to a potentially avoidable, invasive procedure with significant morbidity. It is important to note that, within the National Cancer Database (NCDB), a hospital-based cancer outcomes database of more than 1,500 Commission on Cancer-accredited cancer programs, 76% of pathologically node-negative patients treated in 2013–2014 underwent SLNB only. Adding the requirement of being clinically node-negative to this pathologically node-negative cohort yields an unchanged proportion of women undergoing SLNB only (77%). Equally as important, only 8% of clinically node-positive patients were pathologically node-negative. In addition, a recent abstract reported only a 0.5% likelihood of nodal downstaging (clinically node-positive to pathologically node-negative) in women with Stage 1–3 hormone receptor-positive breast cancer.[45] Therefore, our inability to identify clinically node-negative cases is not likely to alter our results appreciably. To our knowledge, no database includes clinical *and* pathologic stage *and* provider information. While the NCDB includes clinical and pathologic stage, it does not include information on surgeon characteristics, preventing the replication of this study in NCDB.

Inherent to claims-based, retrospective studies is our inability to determine the factors and reasons (patient, tumor, surgeon, hospital) for starting with or converting to ALND in pathologically node-negative patients. Therefore, we cannot ascertain the "appropriateness" of 49% of the cohort undergoing ALND. Our purpose was to examine the type of axillary

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surgery performed; we make no value judgements regarding the appropriateness of that decision-making. For patients who underwent initial ALND, we do not know whether these cases involved surgeons who did not offer SLNB because of preoperative clinical or radiographic concerns for axillary lymph node metastasis, do not perform SLNB, or are at a facility where the resources to perform SLNB are not available. For patients who converted to ALND after SLNB, we do not know whether this was because a sentinel node was not identified or, if identified, whether the surgeon was confident that the sentinel node(s) was/were accurately identified, or if there was intraoperative concern for axillary (sentinel or non-sentinel) metastasis. We cannot determine what proportion of patients underwent a preoperative axillary ultrasound or had intraoperative frozen section of any lymph nodes (sentinel or non-sentinel) performed. Lastly, since this study was confined to Medicare patients, our findings may not be generalizable to younger populations.

In conclusion, this study provides important clinical and policy relevant findings regarding the translation of the efficacy of SLNB established in clinical trials to community-based, population-wide effectiveness. First, given the higher likelihood of pathologically node-negative women undergoing ALND by low volume surgeons, patients and referring providers should be cognizant of their surgeons' experience with breast cancer cases and SLNB. Second, since half of pathologically node-negative patients underwent an ALND, optimization of both preoperative nodal assessment (e.g., axillary ultrasound, preoperative biopsy for clinically node-positive patients) and intraoperative management of lymph nodes (e.g., frozen section of suspicious nodes, particularly if a negative result would preclude immediate ALND) to appropriately select patients for potentially SLNB only surgery is necessary. Furthermore, references (e.g. Operative Standards for Cancer Surgery[46] by the American College of Surgeons Clinical Research Program and the Alliance for Clinical Trials in Oncology; a troubleshooting guide for SLNB[47]) and policies on appropriate surgeon training and competency in SLNB (e.g. training programs, societal proficiency guidelines and consensus statements) should be considered to assure the optimal performance of SLNB in the community. Lastly, since post-treatment lymphedema is associated with significantly decreased quality of life and increased costs[4–10] and we estimate that almost a quarter of all expected lymphedema cases are due to potentially avoidable ALNDs, regionalization of initial surgical care to centers with the necessary experience and resources to perform SLNB may need to be considered to decrease rates of ALND and ultimately lymphedema and other arm morbidity among breast cancer survivors.

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Table 1

Patient, tumor and surgeon characteristics, by type of axillary surgery, among 7,686 pathologically node-negative women

	Total cohort N=7,686	SLNB only N=3,889 (51%)	ALND* N=3,797 (49%)	p-value
Patient characteristics				
Age (years)				0.003†
66 – 69	1,774 (23%)	940 (24%)	834 (22%)	
70 – 74	2,167 (28%)	1,124 (29%)	1,043 (28%)	
75 – 79	1,857 (24%)	932 (24%)	925 (24%)	
80+	1,888 (25%)	893 (23%)	995 (26%)	
Mean (SD)	74.9 (6.1)	74.7 (6.0)	75.2 (6.2)	
Race				0.16
White	6,798 (88%)	3,466 (89%)	3,332 (88%)	
Black	496 (6%)	233 (6%)	263 (7%)	
Other	392 (5%)	190 (5%)	202 (5%)	
Comorbidity				0.001
0	4,106 (53%)	2,156 (55%)	1,950 (51%)	
1	2,136 (28%)	1,044 (27%)	1,092 (29%)	
2+	1,444 (19%)	689 (18%)	755 (20%)	
Extent of disease				
Tumor size (cm)				
0 – 2	6,015 (78%)	3,161 (81%)	2,854 (75%)	<0.001†
> 2 – 5	1,560 (20%)	665 (17%)	895 (24%)	
Unknown	111 (1%)	63 (2%)	48 (1%)	
Mean (SD)	1.5 (0.9)	1.4 (0.8)	1.6 (0.9)	
Tumor grade				<0.001
Low	2,125 (28%)	1,136 (29%)	989 (26%)	
Moderate	3,548 (46%)	1,805 (46%)	1,743 (46%)	
High	1,754 (23%)	828 (21%)	926 (24%)	
Unknown	259 (3%)	120 (3%)	139 (4%)	
Hormone receptor status				<0.001
Positive	6,371 (83%)	3,290 (85%)	3,081 (81%)	
Negative	1,012 (13%)	478 (12%)	534 (14%)	
Unknown	303 (4%)	121 (3%)	182 (5%)	
AJCC tumor stage				<0.001
I	6,126 (80%)	3,224 (83%)	2,902 (76%)	
II	1,560 (20%)	665 (17%)	895 (24%)	

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	Total cohort N=7,686	SLNB only N=3,889 (51%)	ALND* N=3,797 (49%)	p-value
Number of lymph nodes removed				<0.001†
1 – 5	5,961 (78%)	3,535 (91%)	2,426 (64%)	
6 – 10	928 (12%)	280 (7%)	648 (17%)	
11 – 15	463 (6%)	56 (1%)	407 (11%)	
16+	334 (4%)	18 (0.5%)	316 (8%)	
Mean (SD)	4.3 (4.7)	2.8 (2.5)	5.9 (5.8)	
Surgeon factor				
Surgeon volume				
Low	1,882 (25%)	808 (21%)	1,074 (28%)	<0.001
Medium	3,234 (42%)	1,704 (44%)	1,530 (40%)	
High	2,570 (33%)	1,377 (35%)	1,193 (31%)	

Abbreviations: AJCC, American Joint Committee on Cancer; SD, standard deviation

*ALND defined as patients who either underwent initial SLNB and converted to ALND (n=3,015) or underwent ALND only (n=782).

†For continuous variable comparison, p<0.001

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Table 2

Logistic regression model with physician-specific random effects predicting the likelihood of pathologically node-negative women undergoing ALND

Characteristics	Odds Ratio	95% CI	p-value
Surgeon volume			<0.001
Low	1.00		
Medium	0.69	0.51 – 0.82	
High	0.59	0.45 – 0.76	
Patient characteristics			
Age (years)			0.26
66 – 69	1.00		
70 – 74	1.04	0.89 – 1.20	
75 – 79	1.11	0.94 – 1.30	
80+	1.16	0.99 – 1.36	
Race			0.30
White	1.00		
Black	1.00	0.80 – 1.27	
Other	1.24	0.94 – 1.64	
Comorbidity			0.81
0	1.00		
1	1.04	0.91 – 1.18	
2+	1.04	0.89 – 1.20	
Tumor factors			
Tumor size			<0.001
0 – 2	1.00		
> 2 – 5	1.49	1.29 – 1.71	
Missing	0.86	0.54 – 1.38	
Tumor grade			0.66
Low	1.00		
Medium	1.05	0.92 – 1.20	
High	1.11	0.94 – 1.32	
Missing	1.10	0.79 – 1.52	
Hormone receptor status			0.005
Positive	1.00		
Negative	1.12	0.94 – 1.34	
Unknown	1.60	1.19 – 2.15	

Adjusted for SEER state

Abbreviations: ALND, axillary lymph node dissection; CI, confidence interval

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Table 3

Number of nodes removed and estimates of lymphedema and excess lymphedema by type of axillary surgery performed

	SLNB only N=3,889 (51%)	SLNB to ALND N=3,015 (39%)	ALND only N=782 (10%)	Overall cohort N=7,686
No. nodes removed				
Mean (SD)	2.8 (2.5)	4.4 (4.5)	11.7 (6.8)	4.3 (4.7)
Median (Q1–Q3)	2 (1–3)	3 (2–5)	11 (7–16)	3 (1–5)
Lymph node category (n;%)				
1–5	3,535 (91%)	2,276 (76%)	150 (19%)	5,961 (78%)
6–10	280 (7%)	441 (15%)	207 (26%)	928 (12%)
11–15	56 (1.4%)	196 (6%)	211 (27%)	463 (6%)
16+	18 (0.5%)	102 (3%)	214 (27%)	334 (4%)
5-year estimated lymphedema probability	11.0%	14.1%	28.2%	13.9%
Estimated excess lymphedema probability *	0	3.1%	17.2%	2.9%
No. of estimated lymphedema patients †	428	425	221	1,068
No. of estimated excess lymphedema pts ‡	0	93	135	223

Abbreviations: ALND, axillary lymph node dissection; No., number; Q, quartile; SD, standard deviation; SLNB, sentinel lymph node biopsy

* Estimated excess lymphedema probability = lymphedema probability minus the baseline 11.0% estimated lymphedema probability of SLNB only group

† Number of estimated lymphedema patients = total number of patients × estimated lymphedema probability

‡ Number of estimated excess lymphedema patients = total number of patients × estimated excess lymphedema probability