

Supplemental Online Content

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eAppendix 1. Detailed description of study cohorts

eAppendix 2. Methods: Volume Categories

eAppendix 3. Comparison of facility type and breast cancer volume for hospitals ranking in the bottom versus top quintile for procedure performance

eAppendix 4. Trends in performance of low-value breast cancer operations based on facility type

eAppendix 5. Trends in performance of low-value breast cancer operations based on facility volume

This supplemental material has been provided by the authors to give readers additional information about their work.

Appendix A. Detailed description of study cohorts

Axillary lymph node dissection (ALND) for lumpectomy patients with 1-2 positive nodes receiving radiotherapy

For evaluation of ALND rates, the study cohort was designed to mirror inclusion criteria of the American College of Surgeons Oncology Group (ACOSOG) Z0011 trial which informed the recommendation to omit ALND for limited nodal disease. The sample was limited to women diagnosed with invasive breast cancer who received a lumpectomy and post-operative radiotherapy. Only patients with a tumor size ≤ 5 cm (pathologic stage T1-T2) and 1 or 2 positive lymph nodes were included. NCDB does not provide a variable to indicate whether a patient received SLNB or ALND. Following methods previously defined in the literature, patients were classified as receiving ALND if they had eight or more lymph nodes examined. By definition, all patients had at least one lymph node examined, and we assumed that patients who had one to seven lymph nodes examined received SLNB only. A total of 47,174 cases met the eligibility criteria for evaluation of ALND rates.

Lumpectomy re-operation for patients receiving radiotherapy

For evaluation of lumpectomy margin re-operation rates, the study cohort was designed to mirror criteria based on the 2014 SSO/ASTRO consensus statement endorsing a margin of “no tumor on ink”. The sample was limited to women stage I or II invasive breast cancer tumors who received a lumpectomy as the initial operation and received post-lumpectomy adjuvant radiotherapy. Patients who were diagnosed with an excisional biopsy, who received their final operation more than 90 days after their initial operation, and who had positive margins at the final operation were excluded from analysis. NCDB provides information about the final operation that a patient receives; it does not provide information on the initial operation, reason or reoperation, or number of reoperations. Following previously described methods, re-operation was used as a proxy for lumpectomy margin re-excision. Patients who had a time to definitive operation that was greater than the time to first operation were defined as receiving a repeat operation. Patients who received a repeat operation and had either a unilateral or bilateral mastectomy at their final operation were assumed to have had a lumpectomy at their initial operation. A total of 487,443 cases met the eligibility criteria for evaluation of re-operation rates.

Contralateral prophylactic mastectomy (CPM) for patients with unilateral breast cancer

For evaluation of CPM rates, the sample was limited to women with unilateral in situ or invasive stage 0-II breast cancer who received a mastectomy. NCDB does not provide information on high-risk characteristics (e.g. genetic mutations such as BRCA), but we assumed that the incidence of high-risk patients would be stable over time. Patients who received bilateral mastectomy for a unilateral cancer were classified as having received a contralateral prophylactic mastectomy. A total of 372,561 cases met the eligibility criteria for evaluation of CPM rates.

Sentinel lymph node biopsy (SLNB) for women ≥ 70 years old with clinically node negative hormone receptor positive cancer

For evaluation of rates of axillary lymph node evaluation in older patients, the study cohort was limited to women 70 years of age or older with clinically node negative, stage I-II, hormone receptor positive invasive breast cancer. Hormone receptor positivity was defined as tumors that were either estrogen receptor positive (ER+) and/or progesterone receptor positive (PR+). Patients who did not receive any surgical treatment for their primary tumor (either lumpectomy or mastectomy) within 12 months of diagnosis were excluded. Because NCDB does not have a variable to determine whether a patient received SLNB or ALND, all patients who had 1 or more regional lymph nodes examined were defined as receiving axillary evaluation with SLNB. A total of 212,733 cases met the eligibility criteria for evaluation of SLNB rates.

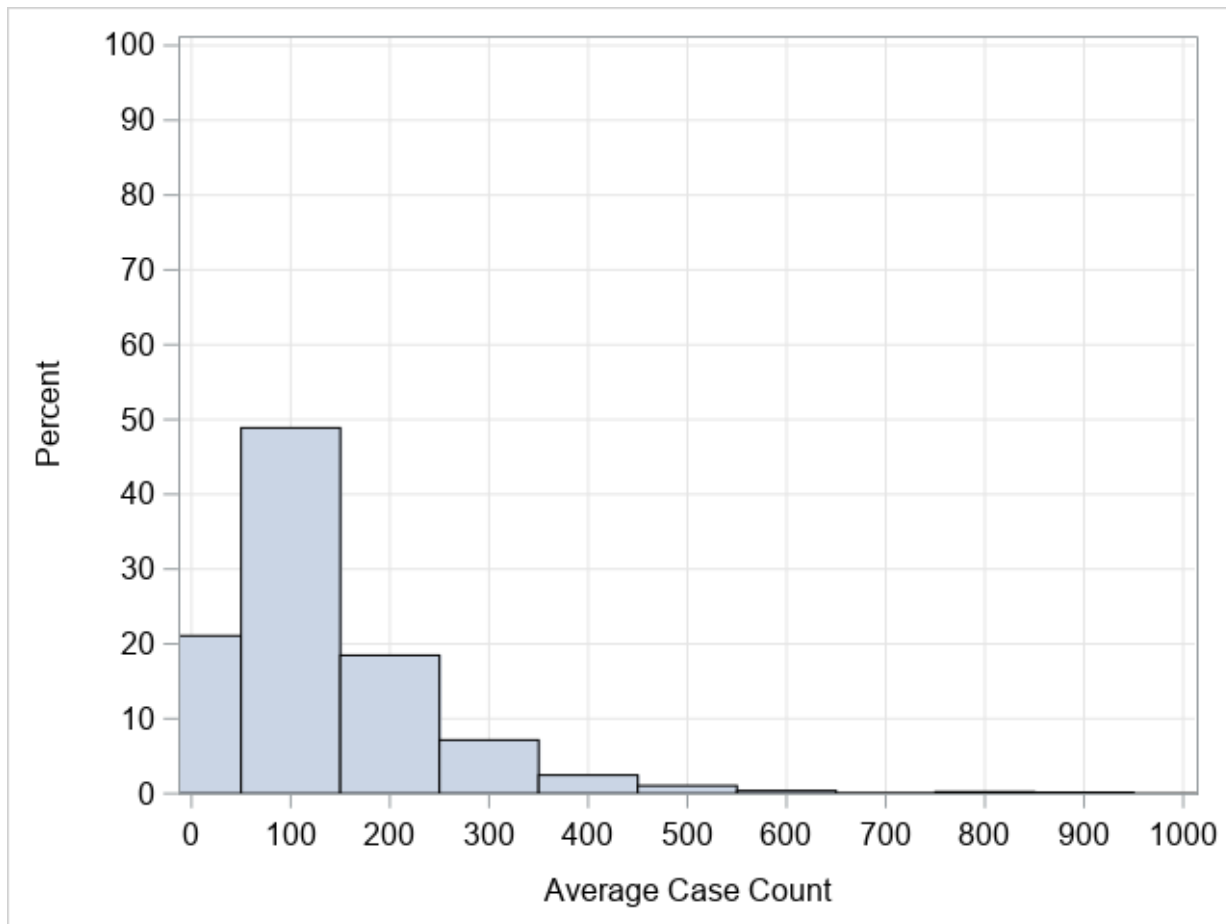
Appendix B. Methods: Volume Categories

eTable 1: Facilities in each volume category by procedure

Procedure	Low Volume	Medium Volume	High Volume	Total Facilities
ALND	54 (9.6%)	260 (46.3%)	248 (44.1%)	562
Re-Operation	596 (48.0%)	388 (31.3%)	257 (20.7%)	1,241
CPM	582 (47.4%)	388 (31.6%)	257 (21.0%)	1,227
SLNB	492 (43.4%)	386 (34.0%)	256 (22.6%)	1,134

eTable 2: Patients from facilities in each volume category by procedure

Procedure	Low Volume	Medium Volume	High Volume	Total Patients
ALND	809 (1.7%)	10,433 (22.1%)	35,932 (76.2%)	47,174
Re-Operation	84,896 (17.4%)	159,703 (32.8%)	242,844 (49.8%)	487,443
CPM	62,986 (16.9%)	119,227 (32.0%)	190,348 (51.1%)	372,561
SLNB	37,405 (17.6%)	74,594 (35.1%)	100,734 (47.4%)	212,733

eFigure 1: Histogram of average annual facility volume (N = 1342 Facilities)

Appendix C. Comparison of facility type and breast cancer volume for hospitals ranking in the bottom versus top quintile for procedure performance

Axillary lymph node dissection (ALND) for lumpectomy patients with 1-2 positive nodes receiving radiotherapy

	Facility Category	Bottom Quintile	Top Quintile
Breast Cancer Volume	Low Volume	3 (3.7%)	1 (1.3%)
	Medium Volume	21 (25.6%)	24 (30.8%)
	High Volume	58 (70.7%)	53 (68.0%)
Facility Type	Community Cancer Program	3 (3.7%)	2 (2.6%)
	Comprehensive Community Cancer Program	38 (46.3%)	33 (42.3%)
	Academic/Research Program	24 (29.3%)	31 (39.7%)
	Integrated Network Cancer Program	17 (20.7%)	12 (15.4%)

Lumpectomy re-operation for patients receiving radiotherapy

	Facility Category	Bottom Quintile	Top Quintile
Breast Cancer Volume	Low Volume	43 (47.3%)	43 (53.1%)
	Medium Volume	28 (30.8%)	24 (29.6%)
	High Volume	20 (22.0%)	14 (17.3%)
Facility Type	Community Cancer Program	14 (15.4%)	10 (12.4%)
	Comprehensive Community Cancer Program	49 (53.9%)	33 (40.7%)
	Academic/Research Program	13 (14.3%)	23 (28.4%)
	Integrated Network Cancer Program	15 (16.5%)	15 (18.5%)

Contralateral prophylactic mastectomy (CPM) for patients with unilateral breast cancer

	Facility Category	Bottom Quintile	Top Quintile
Breast Cancer Volume	Low Volume	39 (48.8%)	46 (50.0%)
	Medium Volume	25 (31.3%)	23 (25.0%)
	High Volume	16 (20.0%)	23 (25.0%)
Facility Type	Community Cancer Program*	17 (21.3%)*	2 (2.2%)*
	Comprehensive Community Cancer Program	36 (45.0%)	46 (50.0%)
	Academic/Research Program	18 (22.5%)	23 (25.0%)
	Integrated Network Cancer Program*	9 (11.3%)*	21 (22.8%)*

Sentinel lymph node biopsy (SLNB) for women ≥ 70 years old with clinically node negative hormone receptor positive cancer

	Facility Category	Bottom Quintile	Top Quintile
Breast Cancer Volume	Low Volume	39 (48.2%)	40 (52.0%)
	Medium Volume	27 (33.3%)	21 (27.3%)
	High Volume	15 (18.5%)	16 (20.8%)
Facility Type	Community Cancer Program	10 (12.4%)	13 (16.9%)
	Comprehensive Community Cancer Program**	25 (30.9%)**	37 (48.1%)**
	Academic/Research Program**	30 (37.0%)**	16 (20.8%)**
	Integrated Network Cancer Program	16 (19.8%)	11 (14.3%)

*p<.001, **p=.050

Appendix D. Trends in performance of low-value breast cancer operations based on facility type

Axillary lymph node dissection (ALND) for lumpectomy patients with 1-2 positive nodes receiving radiotherapy

Facility Type	% 2004	% 2010	% 2011	% 2016	% Relative Reduction (2004-2016)	Δ 2004-2010	Δ 2010-2011	Δ 2011-2016
Community Cancer Program	42.0	45.7	28.3	17.9	57.4	3.6	-17.3	-10.4
Comprehensive Community Cancer Program	60.0	59.0	27.1	14.3	76.2	-1.0	-31.9***	-12.8***
Academic Research Program	68.3	64.8	37.4	14.5	78.8	-3.5**	-27.4***	-22.9***
Integrated Network Cancer Program	62.6	66.2	29.1	13.4	78.6	3.6	-37.1***	-15.7***

Lumpectomy re-operation for patients receiving radiotherapy

Facility Type	% 2004	% 2013	% 2014	% 2016	% Relative Reduction (2004-2016)	Δ 2004-2013	Δ 2013-2014	Δ 2014-2016
Community Cancer Program	19.2	19.1	15.5	15.4	19.8	0.0	-3.6***	-0.1
Comprehensive Community Cancer Program	20.4	19.4	16.6	15.7	23.0	-1.0***	-2.7***	-0.9***
Academic Research Program	21.9	19.1	16.7	15.4	29.7	-2.8***	-2.4**	-1.2***
Integrated Network Cancer Program	20.2	19.2	16.7	15.9	21.3	-1.0***	-2.6**	-0.8***

Contralateral prophylactic mastectomy (CPM) for patients with unilateral breast cancer

Facility Type	% 2004	% 2006	% 2007	% 2016	Δ 2004-2006	Δ 2006-2007	Δ 2007-2016
Community Cancer Program	7.9	10.9	12.9	27.6	3.0	2.0	14.7***
Comprehensive Community Cancer Program	10.9	13.4	18.9	27.5	2.5***	5.5***	8.6***
Academic Research Program	12.1	12.5	14.7	25.8	0.4	2.3***	11.1***
Integrated Network Cancer Program	12.6	16.4	17.6	32.0	3.7*	1.2*	14.4***

Sentinel lymph node biopsy (SLNB) for women ≥70 years old with clinically node negative hormone receptor positive cancer

Facility Type	% 2004	% 2012	% 2013	% 2016	Δ 2004-2012	Δ 2012-2013	Δ 2013-2016
Community Cancer Program	73.5	86.8	88.9	87.9	13.2***	2.1	-0.9
Comprehensive Community Cancer Program	79.0	87.0	87.1	87.4	8.0***	0.1	0.3
Academic Research Program	75.3	85.9	85.3	84.2	10.6***	-0.6	-1.1
Integrated Network Cancer Program	74.8	87.7	88.1	87.4	12.9***	0.4	-0.8

*p<.05, **p<.01, ***p<.001

Appendix E. Trends in performance of low-value breast cancer operations based on facility volume

Axillary lymph node dissection (ALND) for lumpectomy patients with 1-2 positive nodes receiving radiotherapy

	% 2004	% 2010	% 2011	% 2016	% Relative reduction (2004-2016)	Δ 2004-2010	Δ 2010-2011	Δ 2011-2016
Low Volume	60.5	65.6	28.3	13.6	77.5	5.2	-37.3***	-14.7***
Medium Volume	62.1	63.8	42.8	17.3	72.3	1.7	-21.0***	-25.4***
High Volume	65.2	62.1	24.0	13.5	79.3	-3.1**	-38.1***	-10.5***

Lumpectomy re-operation for patients receiving radiotherapy

	% 2004	% 2013	% 2014	% 2016	% Relative reduction (2004-2016)	Δ 2004-2013	Δ 2013-2014	Δ 2014-2016
Low Volume	19.1	17.6	14.9	15.1	20.9	-1.5**	-2.7***	0.1
Medium Volume	19.4	18.0	15.8	15.3	21.1	-1.4***	-2.2***	-0.5
High Volume	22.1	20.6	17.6	16.0	27.6	-1.5	-2.9*	-1.7

Contralateral prophylactic mastectomy (CPM) for patients with unilateral breast cancer

	% 2004	% 2006	% 2007	% 2016	Δ 2004-2006	Δ 2006-2007	Δ 2007-2016
Low Volume	7.3	9.0	12.6	23.6	1.7	3.5*	11.0***
Medium Volume	9.5	12.1	15.0	26.5	2.6***	3.0***	11.5***
High Volume	13.7	15.0	18.1	29.2	1.3*	3.1***	11.1***

Sentinel lymph node biopsy (SLNB) for women ≥70 years old with clinically node negative hormone receptor positive cancer

	% 2004	% 2012	% 2013	% 2016	Δ 2004-2012	Δ 2012-2013	Δ 2013-2016
Low Volume	79.4	86.5	87.2	88.1	7.1***	0.7	0.9
Medium Volume	77.3	86.8	87.6	86.6	9.4***	0.8	-1.1*
High Volume	77.2	87.3	86.5	86.1	10.1***	-0.8	-0.4

*p<.05, **p<.01, ***p<.001