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Impact of experience in breast cancer surgery on survival: the role of quality of care in a registry-based cohort

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Summary

AIMS OF THE STUDY: Previous studies have suggested that the surgeon's experience in breast cancer surgery may affect patient survival. In this registry-based retrospective cohort study, we examined whether quality of care could partly explain this association.

METHODS: All invasive breast cancers operated on in the private sector between 2000 and 2009 were identified in the Geneva Cancer Registry and followed up for 5 years. Surgeons were classified according to their experience into three categories: ≤5, 6–10, >10 breast cancer operations performed per year. We extracted patient and tumour characteristics. Quality of care was scored as the proportion of 11 quality indicators correctly fulfilled for each patient. Breast cancer-specific mortality was examined with a Cox model adjusted for variables known to affect survival, surgeon experience, and quality of care.

RESULTS: A total of 1489 patients were operated on by 88 surgeons; 50 patients (3.4%) died from breast cancer during the 5 years of follow-up. Socioeconomic status and country of birth of the patients, as well as period of diagnosis, differed according to the surgeons' experience. Quality of care provided improved with surgeon's experience. Surgeons performing >10 operations/year more frequently assessed histology before surgery, excised sentinel lymph nodes, removed ≥10 lymph nodes, and prescribed adjuvant radiotherapy when indicated. Crude breast cancer-specific mortality was lower in patients treated by surgeons performing >10 compared with ≤5 operations/year (hazard ratio [HR] 0.34, 95% confidence interval [CI] 0.17–0.67; p = 0.002). The strength of the association decreased after adjustment for patient and tumour characteristics (HR 0.45, 95% CI 0.21–0.94; p = 0.034) and decreased further after adjustment for quality of care (HR 0.51, 95% CI 0.24–1.08, p = 0.078).

CONCLUSIONS: The association between surgeon's experience and 5-year breast cancer survival is at least partly explained by quality of care, patient and tumour characteristics. Further investigations on the impact of other quality indicators such as multidisciplinary networks are needed.

Keywords: *quality of care, breast cancer, survival, caseload, surgeon volume*

Introduction

Despite increasing effectiveness of adjuvant treatments, surgery remains a central component of the treatment for breast cancer. Since the middle of the 1990s, studies started reporting that the surgeon's experience in breast cancer surgery could influence the prognosis of breast cancer patients [1, 2], and suggested improved survival of patients treated by highly experienced surgeons or in high-volume hospitals [3–18]. A meta-analysis suggested that the surgeon's experience was a stronger predictor of survival than the hospital volume [19].

However, why the surgeon's experience could influence breast cancer mortality remains unclear. The authors of two reviews highlighted weaknesses in previously published studies. Most studies were based on administrative data, did not adjust their analyses for differences in the patient characteristics and analysed overall mortality, known to be strongly influenced by patients' co-morbidities [20, 21]. Finally, they suggested that the observed differences in survival could be explained by differences in the quality of breast cancer management (not limited to the surgery).

Switzerland has one of the most expensive healthcare system worldwide [22, 23] and the canton of Geneva is among those with the highest medical density, with approximately 5 physicians per 1000 inhabitants. In this canton, a large proportion of breast cancer surgery is performed in the private sector, sometimes by breast cancer surgeons who perform fewer than five breast cancer operations per year. However, Geneva provides some of the best quality of care for breast cancer in Switzerland [24] and has breast can-

cer survival rates that are among the highest in Switzerland and Europe [25–27].

The aim of this population-based retrospective cohort study was to investigate whether the association between surgeon's experience and breast cancer mortality was also true in this very specific context, even after adjustment for patient and tumour characteristics, and whether this association could be confounded by the quality of care provided.

Material and methods

This study is reported according to the RECORD extension [28] of the STROBE statement [29] for reporting observational studies using routinely collected health data.

Ethical approval

Formal ethical approval and patient consent for this study was not required. The Geneva Cancer Registry (GCR) has a general authorisation [30], to collect nominative data and to analyse the anonymised data.

Design and setting

This retrospective cohort study was based on data routinely collected by the GCR, which has recorded all incident cancers occurring in Geneva, Switzerland (approximately 480,000 inhabitants in 2014) since 1970. The data recorded include sociodemographic variables, tumour characteristics coded according to the International Classification of Diseases for Oncology (ICD-O) [31], stage at diagnosis (coded according to the Tumor, Node, Metastasis Classification of Malignant Tumors [32]), and treatment received within 6 months of diagnosis, including the identity of the physician in charge of the first treatment for the patient, for the private sector.

Cohort identification

Between 2000 and 2009, 3733 patients were diagnosed with invasive breast cancer (ICDO-3 C50.0-6, C50.8-9, behaviour code/3) of whom 1813 (48.6%) were operated on in the private sector. We excluded 57 patients (3.1%) with previous invasive breast cancer, 151 (8.3%) who did not undergo surgery and 116 (6.4%) who did so after having received neoadjuvant treatment. Eventually, we included 1489 patients with breast cancer who underwent surgery in the private sector.

Outcomes

The primary outcome of this study was the 5-year breast cancer-specific survival of patients according to surgeon's experience, adjusted for variables known to influence survival, for patient and tumour characteristics that were significantly associated with the surgeon's experience or patient survival in the present cohort, and for quality-of-care indicators.

Variables of interest

Surgeon experience

To define surgeon experience, we calculated for each surgeon the average number of breast cancer operations performed per year among the resident population. In order to avoid fluctuations due to various reasons (e.g., decreasing activity during the last years of the surgeon's working life), we considered only the 3 years, between 2000 and 2009, during which the surgeon performed the highest number of breast cancer operations. We then stratified the surgeons into three categories: those performing ≤5, 6–10 or >10 breast cancer operations per year.

Patient characteristics

The patient characteristics extracted from the GCR database included age (<50, 50–69, 70–79, ≥80 years), period of diagnosis (2000–2002, 2003–2005, 2006–2009), socioeconomic status coded according to the last occupation (high, medium, low, unknown), country of birth (Switzerland, Southern Europe, other), method of breast cancer detection (mammography screening, clinical screening, breast self-examination, other [including symptoms or incidental finding], unknown), and familial risk of breast cancer (high, medium, none, unknown).

Tumour characteristics

The tumour characteristics considered included stage (I, II, III, IV, unknown) [30], lymph node invasion (no, yes, unknown), tumour grade (well, moderately, or poorly differentiated, unknown), tumour histology (ductal, lobular, other), oestrogen and progesterone receptor status (positive if ≥1% expressed, negative, unknown) and human epidermal growth factor receptor 2 (HER2) status (positive, negative, unknown). Information on HER2 has been available only since 2001.

Indicators of quality of care

State-of-the-art breast cancer management was defined according to the quality indicators described by the European Society of Breast Cancer Specialists (EUSOMA) [33]. We selected nine indicators for which information was available from the GCR database: (1) reported hormone receptor immune-activity, tumour size, and grading; (2) histological assessment before surgery; (3) a single operation for the primary tumour (excluding reconstruction); (4) sentinel lymph node excision for clinically negative axillae; (5) ≥10 lymph nodes removed when axillary dissection performed; (6) breast-conserving surgery for tumours ≤3 cm; (7) radiotherapy if indicated (after breast-conserving surgery if no metastasis or after mastectomy for pT3 or pT4 or positive margin or ≥pN2a); (8) endocrine therapy for oestrogen-receptor positive tumours; and (9) chemotherapy for oestrogen-receptor negative tumours >1 cm or with a positive lymph node (we also considered an age of ≤35 years as an indication for chemotherapy, according to the 2003 Saint Gallen Consensus [34]). We added two additional criteria, not included in EUSOMA: (10) axillary lymph node dissection if clinical involvement or positive sentinel lymph node biopsy and (11) presence of negative margins after the last surgery. Each indicator was scored 1 when correctly performed or 0 if not correctly performed, and was omitted from the score if not applicable to the patient.

For each patient, we calculated the proportion of pertinent indicators correctly fulfilled, as explained in detail in a previous study [35]. This overall quality-of-care score was categorised as <75%, 75–90% or 90–100% of the items fulfilled.

In order to allow indirect comparison with the public sector, we additionally present the data reported in a previously published study on a similar cohort from a public breast cancer unit [35].

Breast cancer-specific mortality

The GCR performs active follow-up yearly, by linking the GCR files with those of the Cantonal Population Office. The cause of death is provided by the Federal Office for Statistics, and coded according to the International Statistical Classification of Diseases and Related Health Problems [29]. The exact cause of death is confirmed by a physician at the GCR after consulting clinical records and/or inquiring of the patient's physician.

Statistical analysis

Univariate associations

Surgeon experience

The patient and tumour characteristics, and the 11 individual items included in the quality-of-care score were reported according to the surgeon's experience as numbers (percentages) or means (95% confidence intervals [CIs]), and compared with a χ^2 test or analysis of variance (ANOVA), as appropriate, to identify the variables significantly associated with surgeon experience.

5-year survival

All patients were followed up from the date of confirmation of a breast cancer diagnosis until 31 December 2014, death or the date of loss to follow-up, whichever occurred first. Only deaths from breast cancer were considered. Each variable (patient and tumour characteristics) was included in a univariate Cox regression model to identify those significantly associated with 5-year breast cancer-specific mortality.

The crude association between surgeon experience and 5-year breast cancer-specific survival was examined graphically with Kaplan–Meier curves, and a Cox regression model was constructed to report the hazard ratios (HRs) and 95% CIs for comparison of breast cancer mortality in patients treated by surgeons performing 6–10 and >10 breast cancer operations/year with those treated by surgeons performing ≤5 operations/year (baseline).

Multivariate model

We used a multivariate Cox regression model including all variables known to be strongly associated with breast cancer-specific mortality (age, tumour stage, grade, and oestrogen and progesterone receptor status), and the patient or tumour characteristics that were shown to be associated with either 5-year breast cancer-specific survival or with surgeon experience in the univariate analyses. A variable was then dropped from the model if it were not significantly associated with the outcome, did not contribute significantly to the fit of the model to the data, established with a likelihood ratio test comparing the model including the variable with one excluding it ($p > 0.1$), or did not act as a confounder, evident as a change in HR of >10%.

Finally, we quantified the impact of the quality of care by introducing the quality-of-care score into the last multivariate model.

Missing data for different variables were retained in the models as a category labelled "unknown". We considered differences as statistically significant at $p < 0.05$; all p-values reported are two-sided. The proportional hazard assumption was assessed graphically.

All analyses were performed using STATA 15 (StataCorp, College Station, TX 77845, USA).

Results

Description of the cohort

During the study period, 88 surgeons operated on 1489 breast cancer patients. Most (n = 67) surgeons were gynaecologists; 18 were thoracic and 3 were plastic surgeons. A total of 651 breast cancer patients (44%) were operated on by 5 surgeons who performed >10 operations/year, 434 (29%) by 12 surgeons who performed 6–10, and 404 (27%) by 71 surgeons who performed ≤5. Among the latter group, 37 (9%) women were operated on by one of the 25 surgeons who performed ≤1 breast cancer intervention per year.

Patient and tumour characteristics

During the study period, the patients recruited by the surgeons performing >10 operations/year increased from 39 to 50%, whereas recruitment by the surgeons performing ≤5 decreased from 31 to 21% ($p < 0.001$). Compared with the patients treated by the latter, those treated by surgeons performing >10 operations/year were more often of a higher socioeconomic status and were less frequently born in Southern Europe (table 1). Although there were differences in the proportion of "unknown data" for some variables, tumour characteristics did not differ significantly across the surgeon groups (table 2). In comparison with previously published data from the public sector [35] patients tended to be younger, from higher socio-economic status and more often born in Switzerland. The tumour characteristics, however, were similar (tables 1 and 2).

Quality-of-care indicators and overall score

Table 3 presents the 11 quality indicators according to surgeon experience. Significant differences across the categories of surgeon experience were observed for histological assessment before surgery, sentinel lymph node procedure (when indicated), and ≥10 lymph nodes removed during axillary dissection. The mean overall quality indicator score was high in all groups (above 82%), but was higher in the women treated by surgeons performing >10 operations/year; 50.5% of their patients benefited from >90% of pertinent items fulfilled. This proportion was 47.2% in patients treated by surgeons performing 6–10 operations/year and 34.7% for those treated by surgeons performing ≤5 ($p < 0.001$). Most of the EUSOMA minimum requirements were reached except for sentinel lymph node excision (if indicated) and the number of lymph nodes removed, which did not reach 90% and 95%, respectively, in any group. Also, the administration of chemotherapy when indicated failed to reach the 80% required by EUSOMA. Interestingly, the public sector also failed to reach these standards (table 3).

Five-year breast cancer-specific survival

The 1489 patients represented a total of 7046.9 person-years of follow-up.

Univariate analyses

Fifty women died of their breast cancer (3.4%; death rate 7.1/1000 person-years). Of these, 13 (2.0%; 4.2/1000 person-years) were treated by surgeons performing >10, 14 (3.2%, 6.8/1000 person-years) by surgeons performing 6–10, and 23 (5.7%, 12.3/1000 person-years) by surgeons performing ≤5 operations/year.

The crude 5-year breast cancer-specific survival rates were high, but differed significantly across groups (>10: 98%, 95%CI 97–99%; 6–10: 96%, 95% CI 95–98%; and <5, 94%, 95% CI 92–96%; p = 0.004 in a log rank test; fig. 1).

Variables significantly associated with 5-year breast cancer-specific survival in the univariate analyses included age, socioeconomic status, method of breast cancer detection, familial risk of breast cancer, stage, lymph node invasion, grade, histology, and oestrogen and progesterone receptor and HER2 status.

Multivariate analyses

The variables retained in the final Cox model were age, socioeconomic status, stage, lymph node invasion, grade, histology, and oestrogen and progesterone receptor status. A second model was constructed that included the quality-of-care score.

In the crude analysis, the patients operated on by surgeons performing >10 operations/year presented with 66% lower breast cancer-specific mortality than those treated by surgeons performing ≤5 (HR 0.34, 95% CI 0.17–0.67; p = 0.002). Adjustment for patient and tumour characteristics reduced the strength of the association (HR_{adj-1} 0.45, 95% CI 0.21–0.94; p = 0.034). In the final model, additional adjustment for quality of care further decreased the strength of the association (HR_{adj-2} 0.51, 95% CI 0.24–1.08; p = 0.078) and failed to reach statistical significance. The crude HR comparing the patients treated by surgeons performing 6–10 operations/year with those treated by surgeons performing ≤5 followed the same trend. (table 4)

Discussion

This study confirms previously reported findings, highlights new ones and generates several questions. First, as previously reported, we found a statistically significant crude association between high surgeon experience, and improved breast cancer-specific survival in their patients. Second, this study demonstrates that the strength of this association decreases after adjustment for patient and tumour

Table 1: Characteristics of breast cancer patients according to the surgeon's experience (Geneva Cancer Registry 2000–2009).

Characteristics	Private surgeons' experience[a] ≤5 years (n = 404)		Private surgeons' experience[a] 6–10 years (n = 434)		Private surgeons' experience[a] >10 years (n = 651)		p-value[b]	Public BC unit[c] (n = 752)	
	n	%	n	%	n	%		n	%
Age (years) mean (95% CI)	60.6 (59.4–61.7)		59.9 (58.8–61.0)		59.2 (58.3–60.1)		0.188[d]	61.8	
Age (years)							0.606		
<50	80	19.8%	85	19.6%	133	20.4%		141	18.8%
50–69	231	57.2%	268	61.8%	398	61.1%		394	52.4%
70–79	73	18.1%	60	13.8%	93	14.3%		150	19.9%
≥80	20	5.0%	21	4.8%	27	4.1%		67	8.9%
Period of diagnosis							<0.001		
2000–2	154	38.1%	146	33.6%	190	29.2%		350	46.5%
2003–5	133	32.9%	127	29.3%	182	28.0%		402	53.5%
2006–9	117	29.0%	161	37.1%	279	42.9%			
Socioeconomic status							0.026		
High	88	21.8%	122	28.1%	201	30.9%		90	12.0%
Medium	268	66.3%	259	59.7%	386	59.3%		427	56.8%
Low	43	10.6%	42	9.7%	50	7.7%		215	28.6%
Unknown	5	1.2%	11	2.5%	14	2.2%		20	2.7%
Country of birth							0.007		
Swiss	211	52.2%	240	55.3%	344	52.8%		362	48.1%
Southern Europe	99	24.5%	98	22.6%	114	17.5%		258	34.3%
Other	94	23.3%	96	22.1%	193	29.6%		132	17.6%
Method of detection							0.093		
Mammography screening	180	44.6%	212	48.8%	298	45.8%		290	38.6%
Clinical screening	53	13.1%	57	13.1%	64	9.8%		67	8.9%
Breast self-examination	118	29.2%	125	28.8%	201	30.9%		288	38.3%
Other	46	11.4%	35	8.1%	66	10.1%		106	14.1%
Unknown	7	1.7%	5	1.2%	22	3.4%		1	0.1%
Familial risk							0.058		
None	253	62.6%	291	67.1%	378	58.1%		505	67.2%
Medium	97	24.0%	80	18.4%	165	25.3%		173	23.0%
High	25	6.2%	25	5.8%	40	6.1%		68	9.0%
Unknown	29	7.2%	38	8.8%	68	10.4%		6	0.8%

BC = breast cancer; CI = confidence interval [a] Surgeon's experience: mean annual new primary breast cancer (invasive or in situ) operations during the 3 years with the highest number of breast cancer intervention along the study period. [b] p-value of a χ^2 test [c] Data from Taban et al. 2013 [35] [d] p-value for ANOVA test

characteristics, and further decreases after adjustment for measurable indicators of quality of care, suggesting that these factors may, at least partly, explain the previously reported differences in survival. Third, the quality of care provided in the private sector for breast cancer is good and comparable to that of the public breast cancer unit, although some EUSOMA targets were not reached. Fourth, in Geneva, the surgeon's experience may not impact on the 5-year breast cancer-specific survival of patients operated on in the private sector. Finally, other factors reflecting the quality of care should be investigated as they may further decrease the reported association.

What was already known on the topic?

In crude analyses, patients operated on by surgeons performing >10 operations/year had a lower risk of death as a consequence of their breast cancer than patients operated on by surgeons with less experience, which is consistent with the findings of other researchers. Based on 12 of 63 studies published between 1990 and 2010, Gooiker et al. [19] reported that the pooled survival advantage conferred by high-volume surgeons was around 20% (range 10–39%). Other studies have also reported an association between hospital volume and breast cancer survival [19]. In particular, Skinner et al. reported that breast cancer patients operated on by low-volume surgeons in high-volume hospitals had similar outcomes to those of breast cancer patients operated on by high-volume surgeons in low-volume hospitals [4].

Our study also confirms that patients as well as treatments may differ according to surgeon experience [36]. Although better care has generally been observed among breast cancer patients treated by high-volume surgeons, none of the previously published studies have used the EUSOMA criteria to assess the quality of care received. As reported in previous studies, we found that surgeons who performed >10 operations/year more frequently performed a histological assessment before surgery [37, 38], removed sentinel lymph nodes when indicated [39–43], removed an adequate number of axillary lymph nodes when performing axillary clearance [44, 45], and referred their patients for adjuvant radiotherapy when indicated [5, 45, 46].

What does this study add?

What our study newly highlights is that the unexplained association between surgeon experience and breast cancer survival may be partly explained by patient and tumour characteristics, but also by the quality of care provided. In fact, taking these variables into account decreases the association between surgeon experience and breast cancer sur-

Table 2: Characteristics of the tumours according to the surgeon's experience (Geneva Cancer Registry 2000–2009).

Characteristics	Private surgeons' experience[a] ≤5 years (n = 404)		Private surgeons' experience[a] 6–10 years (n = 434)		Private surgeons' experience[a] >10 years (n = 651)		p-value[b]	Public BC unit[c] (n = 752)	
	n	%	n	%	n	%		n	%
Stage							0.251		
I	197	48.8%	224	51.6%	325	49.9%		389	51.7%
II	149	36.9%	167	38.5%	267	41.0%		301	40.0%
III	38	9.4%	29	6.7%	45	6.9%		51	6.8%
IV	7	1.7%	5	1.2%	5	0.8%		4	0.5%
Unknown	13	3.2%	9	2.1%	9	1.4%		7	0.9%
Lymph node invasion							0.017		
No	255	63.1%	283	65.2%	427	65.6%		517	68.8%
Yes	129	31.9%	142	32.7%	214	32.9%		231	30.7%
Unknown	20	5.0%	9	2.1%	10	1.5%		4	0.5%
Grade							0.258		
Well differentiated	132	32.7%	143	32.9%	182	28.0%		250	33.2%
Moderately differentiated	189	46.8%	182	41.9%	317	48.7%		not reported	
Poorly or undifferentiated	79	19.6%	103	23.7%	146	22.4%		not reported	
Unknown	4	1.0%	6	1.4%	6	0.9%		18	2.4%
Histology							0.966		
Ductal	323	80.0%	340	78.3%	521	80.0%		612	81.4%
Lobular	63	15.6%	72	16.6%	101	15.5%		109	14.5%
Other	18	4.5%	22	5.1%	29	4.5%		31	4.1%
Oestrogen receptor status							0.020		
Positive	344	85.1%	383	88.2%	583	89.6%		652	86.7%
Negative	49	12.1%	46	10.6%	65	10.0%		99	13.2%
Unknown	11	2.7%	5	1.2%	3	0.5%		1	0.1%
Progesterone receptor status							0.065		
Positive	313	77.5%	344	79.3%	510	78.3%		552	73.4%
Negative	81	20.0%	85	19.6%	138	21.2%		199	26.5%
Unknown	10	2.5%	5	1.2%	3	0.5%		1	0.1%
HER2 status[d]							0.019		
Positive	47	11.6%	50	11.5%	100	15.4%		135	18.0%
Negative	210	52.0%	235	54.1%	370	56.8%		409	54.4%
Unknown	147	36.4%	149	34.3%	181	27.8%		208	27.7%

BC = breast cancer; CI = confidence interval; HER2 = human epidermal growth factor receptor-2 [a] Surgeon's experience: mean annual new primary breast cancer (invasive or in situ) operations during the 3 years with the highest number of breast cancer intervention along the study period. [b] p-value of a χ^2 test [c] Data from Taban et al. 2013 [35] [d] Available since 2001

vival. This is an important finding, since our study highlights that better survival after breast cancer may be due to better quality of care, and not to the surgeon's technical ability.

Strengths and limitations

One of the strengths of our study is that we examined breast cancer-specific mortality and not overall mortality, which is influenced by patients' comorbidities. A second strength is that we adjusted our final survival model for

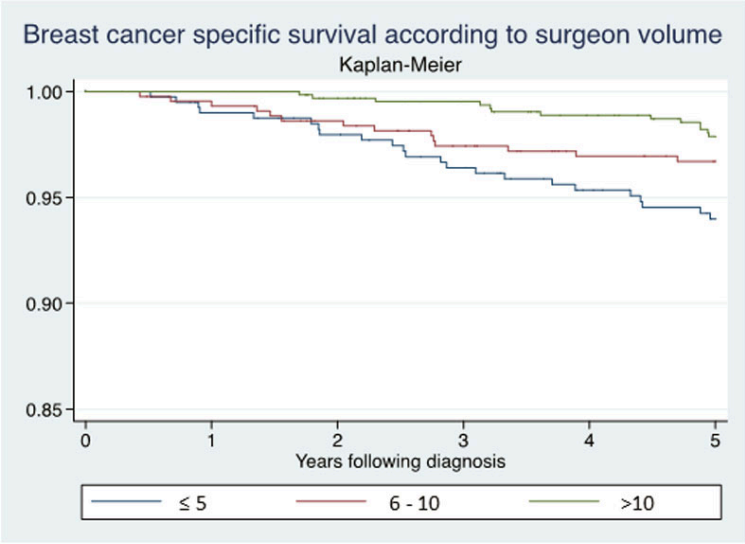
Table 3: Quality of diagnosis assessment and treatment according to the surgeon's experience (Geneva Cancer Registry, 2000–2009).

Indicator of quality		Private surgeon's experience[a] ≤5 years (n = 404)		Private surgeon's experience[a] 6–10years (n = 434)		Private surgeon's experience[a] >10 years (n = 651)		p-value[b]	Public BC unit[c] (n = 752)	
		n	%	n	%	n	%		n	%
Reporting of hormone receptor immune-activity, tumour size, and grading								0.121		
EUSOMA[d] 4b (min: >90%; target: >95%)	Yes	389	96.3%	423	97.5%	640	98.3%		719	95.6%
	No	15	3.7%	11	2.5%	11	1.7%		33	4.4%
Histological assessment before surgery								<0.001		
EUSOMA 3 (min: 80%; target: 90%	Yes	323	80.0%	391	90.1%	610	93.7%		652	86.7%
	No	81	20.0%	43	9.9%	41	6.3%		100	13.3%
Number of surgeries required								0.113		
EUSOMA 9a (min: 80%; target: 90%)	One	340	84.2%	373	85.9%	529	81.3%		651	86.6%
	More	64	15.8%	61	14.1%	122	18.7%		101	13.4%
Surgical margins								0.549		
Non-EUSOMA	Negative	370	91.6%	396	91.2%	606	93.1%		679	90.3%
	Positive	31	7.7%	37	8.5%	44	6.8%		68	9.0%
	Unknown	3	0.7%	1	0.2%	1	0.2%		5	0.7%
Sentinel lymph node excision, if indicated								<0.001		
EUSOMA 9c (min: 90%; target: 95%)	Yes	165	57.5%	242	72.9%	418	82.1%		368	70.5%
	No	122	42.5%	90	27.1%	91	17.9%		160	30.7%
	Not pertinent	117	–	102	–	142	–		224	
Axillary dissection when indicated								0.199		
Non-EUSOMA	Yes	100	89.3%	107	87.0%	184	92.9%		187	85.4%
	No	12	10.7%	16	13.0%	14	7.1%		32	14.6%
	Not pertinent	292	–	311	–	453	–		533	
Number of lymph nodes removed								0.002		
EUSOMA 9d (min: 95%; target: 98%	≥10	137	57.8%	138	67.6%	214	72.1%		281	75.9%
	<10	100	42.2%	66	32.4%	83	27.9%		89	24.1%
	Not pertinent	167	–	230	–	354	–		382	
Breast-conserving surgery when indicated								0.536		
EUSOMA 11a (min: 70%; target: 80%)	Yes	298	86.9%	339	87.6%	489	85.2%		518	79.2%
	No	45	13.1%	48	12.4%	85	14.8%		136	20.8%
	Not pertinent	61	–	47	–	77	–		98	
Radiotherapy use when indicated								0.066		
EUSOMA 10 (min: 90%; target: 95%)	Yes	304	89.7%	349	93.3%	508	93.7%			
	No	35	10.3%	25	6.7%	34	6.3%			
	Not pertinent	65	–	60	–	109	–			
Anti-oestrogen use when indicated								0.877		
EUSOMA 12a (min: 80%; target: 90%)	Yes	295	86.3%	331	86.9%	492	85.7%		611	93.7%
	No	47	13.7%	50	13.1%	82	14.3%		41	6.3%
	Not pertinent	62	–	53	–	77	–		100	
Chemotherapy use when indicated								0.402		
EUSOMA 13a (min: 80%; target: 90%)	Yes	115	75.7%	121	74.2%	172	69.9%		164	56.0%
	No	37	24.3%	42	25.8%	74	30.1%		129	44.0%
	Not pertinent	252	–	271	–	405	–		459	
Quality-of care-score								<0.001		
Mean (SD)		82.6%	(16.0%)	86.8%	(14.3%)	87.7%	(14.1%)	0.01[e]	85.0	
<75%		125	30.9%	94	21.7%	131	20.1%	<0.001	196	27.0%
75–90%		139	34.4%	135	31.1%	191	29.3%		291	40.1%
>90%		140	34.7%	205	47.2%	329	50.5%		265	36.6%

BC = breast cancer; CI = confidence interval; SD = standard deviation [a] Surgeon's experience: mean annual new primary breast cancer (invasive or in situ) operations during 3 years with the highest number of breast cancer intervention along the study period [b] p-value of the χ^2 test leaving non-pertinent out [c] Data from Taban et al. 2013 [35] [d] Del Turco et al. 2010 [33] [e] ANOVA

all patient and tumour characteristics that are known to be associated with survival, or that were associated with surgeon experience or survival in our cohort. Finally, we used well-defined and recognised quality indicators to control for the impact of the quality of care, although we were unable to quantify all of these criteria based on registry data. The main limitation of this study is its observational nature. However, it is unlikely that a randomised clinical trial of this issue will ever be performed for practical and ethical reasons. Furthermore, we cannot exclude residual confounding by unrecorded variables. For example, the GCR collects information on patient characteristics and treatments, but does not collect detailed information regarding the specifics of the surgical procedures used. Also, the GCR records the name of the physician responsible for the first treatment administrated only, and for this reason, patients who had received neoadjuvant chemotherapy (about 6%) had to be excluded from our analyses. The surgeons' experience was probably underestimated in this study because we considered only the operations performed on breast cancer patients living in Geneva. Resident cancer patients represent 75% of all breast cancer patients treated in Geneva. However, we have no reason to believe that the proportion of nonresidents operated on differed according to surgeon experience, and we are quite confident that our categorisation is robust. The cut-offs used to define surgeon experience were lower than those used in most other studies [19], which reflects the reality of a city such as Geneva with both a high number of health providers in the private sector and a small population. Other studies have used various cut-off values to classify surgeon volume [19, 47] and have shown a positive relationship between surgeon volume and breast cancer survival, independently of the cut-offs used. Also, this study focuses on breast cancer patients treated in the private sector; no extrapolation of our results to the public sector can be made, and we were unable to reproduce similar analyses for the public sector since the identity of the surgeons in university hospitals is unclear. However, indirect comparison with a public breast cancer unit during a similar time period showed comparable quality of care [35]. We did not control for the potential impact of "hospital volume", but we are quite confident that, since there are only three private hospitals in Geneva, which are very similar in size, in their recruitment of breast cancer patients and in the quality of care they provide, this should not influence our re-

Figure 1: 5-year survival following breast cancer diagnosis.



# surgeries/year	# patients at risk					
≤ 5	404	393	378	369	356	337
6-10	434	430	420	409	398	393
>10	651	644	628	613	602	587

Table 4: Effect of the surgeon's experience on breast cancer-specific mortality at 5 years (Geneva Cancer Registry, 2000–2009).

Surgeon's experience	Crude Hazard ratio (95% CI)	p-value	Hazard ratio (95% CI) adjusted for patient and tumour characteristics[a]	p-value	Hazard ratio (95% CI) adjusted for patient, tumour characteristics and quality of care[b]	p-value
≤5 surgeries/year	1 (reference)		1 (reference)		1 (reference)	
6–10 surgeries/year	0.55 (0.28-1.06)	0.074	0.63 (0.30-1.32)	0.223	0.67 (0.32-1.40)	0.285
>10 surgeries/year	0.34 (0.17-0.67)	0.002	0.45 (0.21-0.94)	0.034	0.51 (0.24-1.08)	0.078

Surgeon's experience: mean annual new primary breast cancer (invasive or in situ) operations during the 3 years with the highest number of breast cancer intervention along the study period. [a] Adjusted for age, socio-economic status, stage, lymph node invasion, grade, histology, oestrogen and progesterone receptors [c] Additional adjustment for quality of care

sults. Finally, some EUSOMA quality-of-care indicators were unavailable, some have changed in the latest version (i.e., recommendation on the number of lymph nodes to remove), the reasons why some procedures were performed remain unknown, and residual confounding is possible. For example, differences probably exist between surgeons in their access to multidisciplinary care. A multidisciplinary approach, which is now routinely available in specialist breast cancer units, could balance out any effect of the surgeon's experience on survival [48]. At the time the breast cancer patients were enrolled in our study, a breast cancer network, SONGe (réseau de Sénologie et ONco-gynecologie Genevois), attracted some private professionals with a particular interest in the field of breast cancer care. Breast cancer surgeons affiliated to such a network may be more likely to work in a multidisciplinary context and probably have greater experience in breast cancer surgery than those who are not affiliated. Such a network could affect breast cancer-specific survival and could, once adjusted for, further decrease the strength of the association observed.

Conclusions

This study suggests that the previously reported association between surgeon experience and breast cancer mortality may be at least partly explained by patient selection and measurable indicators of quality of care. Further adjustment for variables reflecting quality of care, such as the degree of involvement in a breast cancer network with multidisciplinary meetings and co-operation, should be explored as they may confirm our findings by further decreasing the strength of the association.

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Potential competing interests

The authors declare that they have no direct financial competing interests. FT declares that he belongs to the SONGe network and is one of the surgeons who performed >10 surgeries/year included in the present analysis. The datasets used and analysed are available from the corresponding author on reasonable request.

References

1 Sainsbury R, Haward R, Round C, Rider L, Johnston C. Influence of clinician workload and patterns of treatment on survival from breast cancer. Lancet. 1995;345(8960):1265–70. doi: http://dx.doi.org/10.1016/S0140-6736(95)90924-9. PubMed.

2 Gillis CR, Hole DJ. Survival outcome of care by specialist surgeons in breast cancer: a study of 3786 patients in the west of Scotland. BMJ. 1996;312(7024):145–8. doi: http://dx.doi.org/10.1136/bmj.312.7024.145. PubMed.

3 Stefoski Mikeljevic J, Haward RA, Johnston C, Sainsbury R, Forman D. Surgeon workload and survival from breast cancer. Br J Cancer. 2003;89(3):487–91. doi: http://dx.doi.org/10.1038/sj.bjc.6601148. PubMed.

4 Skinner KA, Helsper JT, Deapen D, Ye W, Sposto R. Breast cancer: do specialists make a difference? Ann Surg Oncol. 2003;10(6):606–15. doi: http://dx.doi.org/10.1245/ASO.2003.06.017. PubMed.

5 Allgood PC, Bachmann MO. Effects of specialisation on treatment and outcomes in screen-detected breast cancers in Wales: cohort study. Br J Cancer. 2006;94(1):36–42. doi: http://dx.doi.org/10.1038/sj.bjc.6602894. PubMed.

6 Bailie K, Dobie I, Kirk S, Donnelly M. Survival after breast cancer treatment: the impact of provider volume. J Eval Clin Pract. 2007;13(5):749–57. doi: http://dx.doi.org/10.1111/j.1365-2753.2006.00748.x. PubMed.

7 Clayforth C, Fritschi L, McEvoy SP, Byrne MJ, Ingram D, Sterrett G, et al. Five-year survival from breast cancer in Western Australia over a decade. Breast. 2007;16(4):375–81. doi: http://dx.doi.org/10.1016/j.breast.2007.01.010. PubMed.

8 Nattinger AB, Laud PW, Sparapani RA, Zhang X, Neuner JM, Gilligan MA. Exploring the surgeon volume outcome relationship among women with breast cancer. Arch Intern Med. 2007;167(18):1958–63. doi: http://dx.doi.org/10.1001/archinte.167.18.1958. PubMed.

9 Chen CS, Liu TC, Lin HC, Lien YC. Does high surgeon and hospital surgical volume raise the five-year survival rate for breast cancer? A population-based study. Breast Cancer Res Treat. 2008;110(2):349–56. doi: http://dx.doi.org/10.1007/s10549-007-9715-4. PubMed.

10 Guller U, Safford S, Pietrobon R, Heberer M, Oertli D, Jain NB. High hospital volume is associated with better outcomes for breast cancer surgery: analysis of 233,247 patients. World J Surg. 2005;29(8):994–9, discussion 999–1000. doi: http://dx.doi.org/10.1007/s00268-005-7831-z. PubMed.

11 Hébert-Croteau N, Brisson J, Lemaire J, Latreille J, Pineault R. Investigating the correlation between hospital of primary treatment and the survival of women with breast cancer. Cancer. 2005;104(7):1343–8. doi: http://dx.doi.org/10.1002/cncr.21336. PubMed.

12 Simunovic M, Rempel E, Thériault ME, Coates A, Whelan T, Holowaty E, et al. Influence of hospital characteristics on operative death and survival of patients after major cancer surgery in Ontario. Can J Surg. 2006;49(4):251–8. PubMed.

13 Gilligan MA, Neuner J, Zhang X, Sparapani R, Laud PW, Nattinger AB. Relationship between number of breast cancer operations performed and 5-year survival after treatment for early-stage breast cancer. Am J Public Health. 2007;97(3):539–44. doi: http://dx.doi.org/10.2105/AJPH.2005.075663. PubMed.

14 Gutierrez JC, Hurley JD, Housri N, Perez EA, Byrne MM, Koniaris LG. Are many community hospitals undertreating breast cancer?: lessons from 24,834 patients. Ann Surg. 2008;248(2):154–62. doi: http://dx.doi.org/10.1097/SLA.0b013e31816c4030. PubMed.

15 Peltoniemi P, Peltola M, Hakulinen T, Häkkinen U, Pylkkänen L, Holli K. The effect of hospital volume on the outcome of breast cancer surgery. Ann Surg Oncol. 2011;18(6):1684–90. doi: http://dx.doi.org/10.1245/s10434-010-1514-1. PubMed.

16 Roohan PJ, Bickell NA, Baptiste MS, Therriault GD, Ferrara EP, Siu AL. Hospital volume differences and five-year survival from breast cancer. Am J Public Health. 1998;88(3):454–7. doi: http://dx.doi.org/10.2105/AJPH.88.3.454. PubMed.

17 Jonker FHW, Hagemans JAW, Verhoef C, Burger JWA. The impact of hospital volume on perioperative outcomes of rectal cancer. Eur J Surg Oncol. 2017;43(10):1894–900. doi: http://dx.doi.org/10.1016/j.ejso.2017.07.009. PubMed.

18 Manchon-Walsh P, Aliste L, Espinàs JA, Prades J, Guarga A, Balart J, et al.; Catalonian Rectal Cancer Group. Improving survival and local control in rectal cancer in Catalonia (Spain) in the context of centralisation: A full cycle audit assessment. Eur J Surg Oncol. 2016;42(12):1873–80. doi: http://dx.doi.org/10.1016/j.ejso.2016.08.009. PubMed.

19 Gooiker GA, van Gijn W, Post PN, van de Velde CJ, Tollenaar RA, Wouters MW. A systematic review and meta-analysis of the volume-outcome relationship in the surgical treatment of breast cancer. Are breast cancer patients better of with a high volume provider? Eur J Surg Oncol. 2010;36(Suppl 1):S27–35. doi: http://dx.doi.org/10.1016/j.ejso.2010.06.024. PubMed.

20 Hébert-Croteau N, Brisson J, Pineault R. Review of organizational factors related to care offered to women with breast cancer. Epidemiol Rev. 2000;22(2):228–38. doi: http://dx.doi.org/10.1093/oxfordjournals.epirev.a018035. PubMed.

21 Hogan AM, Winter DC. Does practice make perfect? Ann Surg Oncol. 2008;15(5):1267–70. doi: http://dx.doi.org/10.1245/s10434-007-9804-y. PubMed.

22 OECD Data. Health spending: https://data.oecd.org/healthres/health-spending.htm (accessed on the 28 September 2018)

23 Reinhardt UE. The Swiss health system: regulated competition without managed care. JAMA. 2004;292(10):1227–31. doi: http://dx.doi.org/10.1001/jama.292.10.1227. PubMed.

24 Ess S, Savidan A, Frick H, Rageth Ch, Vlastos G, Lütolf U, et al. Geographic variation in breast cancer care in Switzerland. Cancer Epidemi-

ol. 2010;34(2):116–21. doi: http://dx.doi.org/10.1016/j.canep.2010.01.008. PubMed.
25 Fisch T, Pury P, Probst N, Bordoni A, Bouchardy C, Frick H, et al. Variation in survival after diagnosis of breast cancer in Switzerland. Ann Oncol. 2005;16(12):1882–8. doi: http://dx.doi.org/10.1093/annonc/mdi404. PubMed.
26 Report WC. Lyon: International Agency for Research on Cancer (IARC); 2008.
27 Sant M, Chirlaque Lopez MD, Agresti R, Sánchez Pérez MJ, Holleczek B, Bielska-Lasota M, et al.; EUROCARE-5 Working Group. Survival of women with cancers of breast and genital organs in Europe 1999-2007: Results of the EUROCARE-5 study. Eur J Cancer. 2015;51(15):2191–205. doi: http://dx.doi.org/10.1016/j.ejca.2015.07.022. PubMed.
28 Benchimol EI, Smeeth L, Guttmann A, Harron K, Moher D, Petersen I, et al.; RECORD Working Committee. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) statement. PLoS Med. 2015;12(10):. doi: http://dx.doi.org/10.1371/journal.pmed.1001885. PubMed.
29 von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP; STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet. 2007;370(9596):1453–7. doi: http://dx.doi.org/10.1016/S0140-6736(07)61602-X. PubMed.
30 Autorisation de la commission d'experts du secret professionnel en matière de recherche médicale: https://www.unige.ch/medecine/rgt/files/7914/6462/0509/Article321bis_1994_Texte_Commission_Experts.pdf (accessed on the 28 September 2018)
31 World Health Organization. ICD-O International classification of diseases for oncology. 3rd ed. Geneva: WHO; 2000. 240 p.
32 TNM Classification of Malignant Tumours (UICC). 6 ed. New York: John Wiley & Sons, Inc.; UICC; 2002 2002.
33 Rosselli Del Turco M, Ponti A, Bick U, Biganzoli L, Cserni G, Cutuli B, et al. Quality indicators in breast cancer care. Eur J Cancer. 2010;46(13):2344–56. doi: http://dx.doi.org/10.1016/j.ejca.2010.06.119. PubMed.
34 Goldhirsch A, Wood WC, Gelber RD, Coates AS, Thürlimann B, Senn HJ. Meeting highlights: updated international expert consensus on the primary therapy of early breast cancer. J Clin Oncol. 2003;21(17):3357–65. doi: http://dx.doi.org/10.1200/JCO.2003.04.576. PubMed.
35 Taban F, Rapiti E, Fioretta G, Wespi Y, Weintraub D, Hugli A, et al. Breast cancer management and outcome according to surgeon's affiliation: a population-based comparison adjusted for patient's selection bias. Ann Oncol. 2013;24(1):116–25. doi: http://dx.doi.org/10.1093/annonc/mds285. PubMed.
36 Hébert-Croteau N, Roberge D, Brisson J. Provider's volume and quality of breast cancer detection and treatment. Breast Cancer Res Treat. 2007;105(2):117–32. doi: http://dx.doi.org/10.1007/s10549-006-9439-x. PubMed.
37 Tamirisa NP, Sheffield KM, Parmar AD, Zimmermann CJ, Adhikari D, Vargas GM, et al. Surgeon and Facility Variation in the Use of Minimally Invasive Breast Biopsy in Texas. Ann Surg. 2015;262(1):171–8. doi: http://dx.doi.org/10.1097/SLA.0000000000000883. PubMed.
38 Eberth JM, Xu Y, Smith GL, Shen Y, Jiang J, Buchholz TA, et al. Surgeon influence on use of needle biopsy in patients with breast cancer: a national medicare study. J Clin Oncol. 2014;32(21):2206–16. doi: http://dx.doi.org/10.1200/JCO.2013.52.8257. PubMed.
39 Posther KE, McCall LM, Blumencranz PW, Burak WE, Jr, Beitsch PD, Hansen NM, et al. Sentinel node skills verification and surgeon performance: data from a multicenter clinical trial for early-stage breast cancer. Ann Surg. 2005;242(4):593–9, discussion 599–602. PubMed.
40 McDermott AM, Wall DM, Waters PS, Cheung S, Sibbering M, Horgan K, et al.; ABS Audit Committee. Surgeon and breast unit volume-outcome relationships in breast cancer surgery and treatment. Ann Surg. 2013;258(5):808–13, discussion 813–4. doi: http://dx.doi.org/10.1097/SLA.0b013e3182a66eb0. PubMed.
41 Yen TW, Laud PW, Sparapani RA, Nattinger AB. Surgeon specialization and use of sentinel lymph node biopsy for breast cancer. JAMA Surg. 2014;149(2):185–92. doi: http://dx.doi.org/10.1001/jamasurg.2013.4350. PubMed.
42 Yen TW, Li J, Sparapani RA, Laud PW, Nattinger AB. The interplay between hospital and surgeon factors and the use of sentinel lymph node biopsy for breast cancer. Medicine (Baltimore). 2016;95(31):. doi: http://dx.doi.org/10.1097/MD.0000000000004392. PubMed.
43 Kong AL, Pezzin LE, Nattinger AB. Identifying patterns of breast cancer care provided at high-volume hospitals: a classification and regression tree analysis. Breast Cancer Res Treat. 2015;153(3):689–98. doi: http://dx.doi.org/10.1007/s10549-015-3561-6. PubMed.
44 Kingsmore D, Hole D, Gillis C. Why does specialist treatment of breast cancer improve survival? The role of surgical management. Br J Cancer. 2004;90(10):1920–5. doi: http://dx.doi.org/10.1038/sj.bjc.6601846. PubMed.
45 Ma M, Bell J, Campbell S, Basnett I, Pollock A, Taylor I. Breast cancer management: is volume related to quality? Clinical Advisory Panel. Br J Cancer. 1997;75(11):1652–9. doi: http://dx.doi.org/10.1038/bjc.1997.281. PubMed.
46 Ingram DM, McEvoy SP, Byrne MJ, Fritschi L, Joseph DJ, Jamrozik K. Surgical caseload and outcomes for women with invasive breast cancer treated in Western Australia. Breast. 2005;14(1):11–7. doi: http://dx.doi.org/10.1016/j.breast.2004.06.008. PubMed.
47 Morche J, Mathes T, Pieper D. Relationship between surgeon volume and outcomes: a systematic review of systematic reviews. Syst Rev. 2016;5(1):204. doi: http://dx.doi.org/10.1186/s13643-016-0376-4. PubMed.
48 Kesson EM, Allardice GM, George WD, Burns HJ, Morrison DS. Effects of multidisciplinary team working on breast cancer survival: retrospective, comparative, interventional cohort study of 13 722 women. BMJ. 2012;344(apr26 1):. doi: http://dx.doi.org/10.1136/bmj.e2718. PubMed.