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Regionalization of care for women with ovarian cancer

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HIGHLIGHTS

- The surgical care of women with ovarian cancer has been concentrated to a smaller number of surgeons over time.
- Fewer hospitals are providing care for women with ovarian cancer.
- There is a modest association between increased surgeon and hospital volume and decreased perioperative mortality.

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ABSTRACT

Objective. Long-term outcomes for women with ovarian cancer are improved when they are treated at high volume hospitals by high volume surgeons. We examined changes over time in surgeon and hospital procedural volume for ovarian cancer and explored the association between volume and perioperative outcomes.

Methods. The New York Statewide Planning and Research Cooperative System (SPARCS) database was used to examine women with ovarian cancer who underwent surgery from 2000 to 2014. Annualized surgeon and hospital procedural volume were estimated and each grouped into quartiles. Changes over time in the annual number of surgeons and hospitals rendering care were estimated. The association between surgeon and hospital volume and perioperative morbidity and mortality were analyzed.

Results. We identified 25,044 patients treated by 2728 surgeons at 213 hospitals. The number of surgeons decreased from 598 surgeons with 1737 patients (mean cases = 3) in 2000, to 278 surgeons who operated on 1503 patients (mean cases = 5) ($P < 0.001$) in 2014, while the mean hospital volume rose from 10 cases to 15 cases over the same time period ($P < 0.001$). There was no difference in morbidity based on surgeon volume (RR = 0.99 for high vs .low volume; 95% CI, 0.91–1.07) while perioperative mortality rates decreased with increasing surgeon volume quartile from 2.6% to 1.9%, 1.3% and 1.3%, respectively ($P < 0.001$). Similarly, there was no association between hospital volume and morbidity (RR = 1.00; 95% CI, 0.88–1.15). In contrast, the mortality rate declined with volume quartile from 2.5% in the lowest volume quartile to 0.9% in the highest volume quartile ($P < 0.001$).

Conclusion. The surgical care of women with ovarian cancer has been concentrated to a smaller number of surgeons and hospitals over time. There was a modest association between increased surgeon and hospital volume and decreased perioperative mortality.

1. Introduction

The association between procedural volume and outcomes in surgery has been well described [1,2]. For many procedures, perioperative outcomes are improved when the operation is performed by high volume surgeons and at high volume hospitals [1–3]. The volume-outcomes paradigm is strongest for high risk procedures that are

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associated with significant perioperative morbidity and mortality [1,2]. Recognition of the volume-outcomes paradigm has led to public reporting of procedural volume, regionalization of care for some procedures, and development of minimum volume standards for some operations [4].

Among gynecologic procedures, the relationship between volume and outcomes is strongest for ovarian cancer-directed surgery [5–9]. Ovarian cancer surgery is highly individualized and often requires extensive cytoreductive efforts including multivisceral resections. These procedures are associated with significant perioperative morbidity and mortality [10,11]. Long-term survival is superior for women with ovarian cancer treated by high volume surgeons and at high volume centers [6,8,12,13]. Given the influence of procedural volume on outcomes, selected referral of women with ovarian cancer to specialized surgeons and centers has been advocated by some [8,9,13–17]. To date, little is known on whether these efforts have influenced patterns of care or referral patterns for women with ovarian cancer [18].

Given the paucity of data describing referral patterns for women with ovarian cancer, we analyzed the patterns of care for women with newly diagnosed ovarian cancer. Specifically, we examined changes in the number of surgeons and hospitals who provide surgical care for women with ovarian cancer and explored the association between physician and facility volume and perioperative outcomes.

2. Methods

2.1. Data source

We utilized the New York Statewide Planning and Research Cooperative System (SPARCS) for analysis. Maintained by the New York State Department of Health, SPARCS is an all-payer database that captures inpatient and outpatient hospital visits [19–22]. Patient demographics, diagnoses and procedures and services are recorded for each encounter. SPARCS data undergoes rigorous, periodic quality reviews. This study was deemed exempt by the institutional review board of Columbia University.

2.2. Patients and procedures

We identified women with ovarian, fallopian tube (ICD-9 183.x) or primary peritoneal (ICD-9 158.8) cancer who underwent oophorectomy with or without hysterectomy from 2000 to 2014. We recorded performance of the following extended procedures for each patient: small bowel resection, rectosigmoid resection, other colon resection, liver resection, bladder resection, diaphragm resection and splenectomy. A procedure score was assigned to each patient based on the number of the above procedures performed at the index admission: 0, 1, or >2. Women with missing or invalid surgeon or hospital identifiers were excluded.

Clinical characteristics included year of surgery, age (<40, 40–49, 50–59, 60–69, ≥70 years), race/ethnicity (white, black, Hispanic, other, unknown), type of admission (elective, emergent/urgent, other/unknown) and insurance status (private, Medicare, Medicaid, none, or other/unknown). Comorbid medical conditions were estimated through calculation of the Elixhauser comorbidity score and categorized as 0, 1, or ≥2 conditions [23].

The surgeon and hospital of record for each patient was noted. The mean annualized procedural volume for each hospital and surgeon was estimated as the total number of procedures the surgeon or hospital performed divided by the number of years in which the surgeon or hospital contributed at least one procedure [3,24]. We created quartiles of approximately equal numbers of patients for hospital and surgeon volume. The association between volume and the outcomes described below were analyzed using volume classified as quartiles and as a continuous variable [25].

2.3. Outcomes

The outcomes of the analysis included perioperative morbidity, in-hospital mortality, and resource utilization. Overall perioperative morbidity was defined as the occurrence of any intraoperative, surgical site, or medical complication as previously described [26]. Transfusion, hospital length of stay and charges were recorded as surrogates for resource utilization. Prolonged length of stay (LOS) was defined as a LOS above the 75th percentile. Total hospital charges were adjusted for inflation to 2014 dollars. Excessive total charges were defined as having the charge above the 75th percentile.

2.4. Statistical analysis

The median and interquartile range of volume were reported for each surgeon or hospital quartile and compared using Kruskal-Wallis tests. Patient demographics, performance of cytoreduction and extended procedures, and the outcomes were reported as frequencies and compared across the quartiles of surgeon and hospital volume using chi-square tests. The number of patients, surgeons, and hospitals were plotted over time.

A mixed-effects log-Poisson model with robust sandwich estimator was fitted to determine predictors of each outcome. The model included surgeon and hospital volume quartiles, cancer, cytoreduction, age, year, race/ethnicity, insurance status, admission type, comorbidity, and procedure score, accounting for hospital- and surgeon-level clustering as random intercepts. To address the loss of power by grouping into quartiles, similar models were fitted including both volumes as linear terms. All analyses were performed with SAS version 9.4 (SAS Institute Inc., Cary, North Carolina). All statistical tests were two-sided. A *P*-value of <0.05 was considered statistically significant.

3. Results

We identified a total of 25,044 patients treated by 2728 surgeons at 213 hospitals from 2004 to 2014. When stratified into quartiles, the median yearly procedural volume for the low volume surgeons was 1.14 (IQR, 1.00–1.67) cases per year compared to 29.60 (IQR, 26.93–39.73) cases per year for the high volume surgeons (Table 1). Patients treated by high volume surgeons were older, more frequently white, more often had private insurance or Medicare, and had more comorbidities ($P < 0.001$ for all). Procedures performed by high volume surgeons were more often elective, included cytoreduction, and were associated with more extended radical procedures ($P < 0.001$ for all).

The median number of cases per year at the low volume hospitals was 6.00 (IQR, 3.07–10.27) compared to 209.40 (IQR, 87.33–209.40) at the high volume centers (Table 2). Patients who received care at high volume hospitals were more often white, privately insured or Medicare recipients, and had more comorbidities ($P < 0.001$ for all). Procedures at high volume hospitals were more often elective, and included cytoreduction and extended radical procedures ($P < 0.001$ for all). High volume surgeons more commonly operated at high volume hospitals ($P < 0.001$).

The mean surgeon volume was 3 (SD = 6) in 2000 in which 598 surgeons operated on 1737 patients. The number of surgeons performing cases declined annually to 278 surgeons who operated on 1503 patients in 2014 with a mean case volume of 5 (SD = 8) ($P < 0.001$) (Fig. 1). In 2000, 166 hospitals provided care for women with ovarian cancer with a mean volume of 10 (SD = 17) cases per year. The number of hospitals declined over time to 97 facilities in 2014 with a mean volume of 15 (SD = 35) surgeries per year ($P < 0.001$) (Fig. 1).

The overall morbidity rate was 31.9% for low volume surgeons, 38.6% for medium low, 36.0% for medium high and 34.8% for high volume physicians ($P < 0.001$) (Table 3). In a multivariate model, the risk ratio for morbidity for high compared to low volume surgeons was 0.99 (95% CI, 0.91–1.07) (Table 4). Perioperative mortality rates for the surgeon

Table 1
Demographics of the ovarian cancer patients undergoing oophorectomy with or without hysterectomy by surgeon volume.

	Annualized surgeon volume								
	Low		Medium Low		Medium High		High		
	N	(%)	N	(%)	N	(%)	N	(%)	*P*-value
All	6275	(25.1)	6209	(24.8)	6138	(24.5)	6422	(25.6)	
Number of surgeons	2604	(95.5)	78	(2.9)	30	(1.1)	16	(0.6)	
Annualized surgeon volume									
Median (IQR)	1.14	(1.00–1.67)	9.50	(8.14–11.07)	17.13	(15.73–19.07)	29.60	(26.93–39.73)	<0.001
Cancer									<0.001
Ovarian cancer	5862	(93.4)	5955	(95.9)	5920	(96.4)	6171	(96.1)	
Peritoneal cancer	413	(6.6)	254	(4.1)	218	(3.6)	251	(3.9)	
Cytoreduction	4117	(65.6)	4902	(78.9)	4892	(79.7)	5530	(86.1)	<0.001
Year									<0.001
2000	667	(10.6)	388	(6.2)	311	(5.1)	371	(5.8)	
2001	602	(9.6)	375	(6.0)	355	(5.8)	373	(5.8)	
2002	584	(9.3)	381	(6.1)	392	(6.4)	449	(7.0)	
2003	492	(7.8)	434	(7.0)	357	(5.8)	421	(6.6)	
2004	491	(7.8)	429	(6.9)	355	(5.8)	452	(7.0)	
2005	458	(7.3)	428	(6.9)	363	(5.9)	409	(6.4)	
2006	431	(6.9)	416	(6.7)	400	(6.5)	468	(7.3)	
2007	389	(6.2)	386	(6.2)	412	(6.7)	471	(7.3)	
2008	392	(6.2)	380	(6.1)	416	(6.8)	436	(6.8)	
2009	331	(5.3)	383	(6.2)	451	(7.3)	428	(6.7)	
2010	337	(5.4)	419	(6.7)	436	(7.1)	475	(7.4)	
2011	310	(4.9)	458	(7.4)	434	(7.1)	444	(6.9)	
2012	292	(4.7)	454	(7.3)	478	(7.8)	411	(6.4)	
2013	272	(4.3)	455	(7.3)	507	(8.3)	432	(6.7)	
2014	227	(3.6)	423	(6.8)	471	(7.7)	382	(5.9)	
Age									<0.001
<40	818	(13.0)	491	(7.9)	434	(7.1)	388	(6.0)	
40–49	1168	(18.6)	985	(15.9)	995	(16.2)	903	(14.1)	
50–59	1608	(25.6)	1690	(27.2)	1635	(26.6)	1728	(26.9)	
60–69	1305	(20.8)	1534	(24.7)	1603	(26.1)	1756	(27.3)	
≥70	1376	(21.9)	1509	(24.3)	1471	(24.0)	1647	(25.6)	
Race/ethnicity									<0.001
White	4163	(66.3)	3743	(60.3)	4497	(73.3)	5147	(80.1)	
Black	679	(10.8)	817	(13.2)	413	(6.7)	201	(3.1)	
Hispanic	528	(8.4)	547	(8.8)	355	(5.8)	227	(3.5)	
Other	571	(9.1)	892	(14.4)	663	(10.8)	437	(6.8)	
Unknown	334	(5.3)	210	(3.4)	210	(3.4)	410	(6.4)	
Admission type									<0.001
Elective	3976	(63.4)	4630	(74.6)	4604	(75.0)	5411	(84.3)	
Emergent/urgent	1882	(30.0)	1428	(23.0)	1167	(19.0)	781	(12.2)	
Other/unknown	417	(6.6)	151	(2.4)	367	(6.0)	230	(3.6)	
Insurance status									<0.001
None	164	(2.6)	163	(2.6)	121	(2.0)	74	(1.2)	
Private	3850	(61.4)	3745	(60.3)	3710	(60.4)	3997	(62.2)	
Medicare	1571	(25.0)	1696	(27.3)	1860	(30.3)	2125	(33.1)	
Medicaid	506	(8.1)	555	(8.9)	360	(5.9)	153	(2.4)	
Other/unknown	184	(2.9)	50	(0.8)	87	(1.4)	73	(1.1)	
Comorbidity									<0.001
0	1533	(24.4)	1068	(17.2)	916	(14.9)	736	(11.5)	
1	1629	(26.0)	1710	(27.5)	1675	(27.3)	1781	(27.7)	
≥2	3113	(49.6)	3431	(55.3)	3547	(57.8)	3905	(60.8)	
Hospital volume, quartiles									<0.001
Low	3555	(56.7)	1673	(26.9)	747	(12.2)	347	(5.4)	
Medium Low	1563	(24.9)	2709	(43.6)	1426	(23.2)	727	(11.3)	
Medium High	701	(11.2)	1363	(22.0)	1966	(32.0)	2562	(39.9)	
High	456	(7.3)	464	(7.5)	1999	(32.6)	2786	(43.4)	
Procedure score									<0.001
0	5140	(81.9)	5240	(84.4)	4826	(78.6)	4742	(73.8)	
1	859	(13.7)	727	(11.7)	861	(14.0)	1052	(16.4)	
≥2	276	(4.4)	242	(3.9)	451	(7.3)	628	(9.8)	
Extended procedures, included in procedure score									
Small bowel resection	280	(4.5)	230	(3.7)	250	(4.1)	286	(4.5)	0.11
Colon resection	476	(7.6)	387	(6.2)	478	(7.8)	676	(10.5)	<0.001
Rectosigmoid resection	421	(6.7)	339	(5.5)	549	(8.9)	726	(11.3)	<0.001
Liver resection	72	(1.1)	28	(0.5)	96	(1.6)	126	(2.0)	<0.001
Bladder resection	27	(0.4)	24	(0.4)	23	(0.4)	48	(0.7)	0.01
Diaphragm resection	112	(1.8)	130	(2.1)	397	(6.5)	492	(7.7)	<0.001
Splenectomy	93	(1.5)	117	(1.9)	185	(3.0)	238	(3.7)	<0.001

Quartiles of annualized surgeon volume were calculated at patient-level.

Table 2
Demographics of the ovarian cancer patients undergoing oophorectomy with or without hysterectomy by hospital volume.

	Annualized hospital volume								
	Low		Medium Low		Medium High		High		
	N	(%)	N	(%)	N	(%)	N	(%)	*P*-value
All	6322	(25.2)	6425	(25.7)	6592	(26.3)	5705	(22.8)	
Number of hospitals	184	(86.4)	18	(8.5)	8	(3.8)	3	(1.4)	
Annualized hospital volume									
Median (IQR)	6.00	(3.07–10.27)	26.20	(20.27–31.00)	57.33	(41.80–69.60)	209.40	(87.33–209.40)	<0.001
Cancer									<0.001
Ovarian cancer	6092	(96.4)	6148	(95.7)	6165	(93.5)	5503	(96.5)	
Peritoneal cancer	230	(3.6)	277	(4.3)	427	(6.5)	202	(3.5)	
Cytoreduction	4385	(69.4)	5005	(77.9)	5389	(81.8)	4662	(81.7)	<0.001
Year									<0.001
2000	626	(9.9)	459	(7.1)	420	(6.4)	232	(4.1)	
2001	519	(8.2)	495	(7.7)	404	(6.1)	287	(5.0)	
2002	562	(8.9)	493	(7.7)	448	(6.8)	303	(5.3)	
2003	518	(8.2)	453	(7.1)	406	(6.2)	327	(5.7)	
2004	509	(8.1)	467	(7.3)	398	(6.0)	353	(6.2)	
2005	476	(7.5)	464	(7.2)	419	(6.4)	299	(5.2)	
2006	460	(7.3)	396	(6.2)	477	(7.2)	382	(6.7)	
2007	416	(6.6)	416	(6.5)	433	(6.6)	393	(6.9)	
2008	406	(6.4)	363	(5.6)	468	(7.1)	387	(6.8)	
2009	347	(5.5)	380	(5.9)	461	(7.0)	405	(7.1)	
2010	341	(5.4)	415	(6.5)	481	(7.3)	430	(7.5)	
2011	328	(5.2)	436	(6.8)	445	(6.8)	437	(7.7)	
2012	268	(4.2)	413	(6.4)	480	(7.3)	474	(8.3)	
2013	278	(4.4)	414	(6.4)	469	(7.1)	505	(8.9)	
2014	268	(4.2)	361	(5.6)	383	(5.8)	491	(8.6)	
Age									<0.001
<40	709	(11.2)	510	(7.9)	487	(7.4)	425	(7.4)	
40–49	1139	(18.0)	1037	(16.1)	998	(15.1)	877	(15.4)	
50–59	1654	(26.2)	1678	(26.1)	1717	(26.0)	1612	(28.3)	
60–69	1364	(21.6)	1594	(24.8)	1665	(25.3)	1575	(27.6)	
>/=70	1456	(23.0)	1606	(25.0)	1725	(26.2)	1216	(21.3)	
Race/ethnicity									<0.001
White	3773	(59.7)	4301	(66.9)	5261	(79.8)	4215	(73.9)	
Black	1023	(16.2)	576	(9.0)	265	(4.0)	246	(4.3)	
Hispanic	586	(9.3)	398	(6.2)	232	(3.5)	441	(7.7)	
Other	789	(12.5)	805	(12.5)	602	(9.1)	367	(6.4)	
Unknown	151	(2.4)	345	(5.4)	232	(3.5)	436	(7.6)	
Admission type									<0.001
Elective	3871	(61.2)	4639	(72.2)	5467	(82.9)	4644	(81.4)	
Emergent/urgent	2146	(33.9)	1582	(24.6)	830	(12.6)	700	(12.3)	
Other/unknown	305	(4.8)	204	(3.2)	295	(4.5)	361	(6.3)	
Insurance status									<0.001
None	294	(4.7)	86	(1.3)	95	(1.4)	47	(0.8)	
Private	3448	(54.5)	3989	(62.1)	4226	(64.1)	3639	(63.8)	
Medicare	1637	(25.9)	1880	(29.3)	2004	(30.4)	1731	(30.3)	
Medicaid	797	(12.6)	400	(6.2)	180	(2.7)	197	(3.5)	
Other/unknown	146	(2.3)	70	(1.1)	87	(1.3)	91	(1.6)	
Comorbidity									<0.001
0	1405	(22.2)	1131	(17.6)	1003	(15.2)	714	(12.5)	
1	1672	(26.4)	1704	(26.5)	1735	(26.3)	1684	(29.5)	
≥2	3245	(51.3)	3590	(55.9)	3854	(58.5)	3307	(58.0)	
Surgeon volume, quartiles									<0.001
Low	3555	(56.2)	1563	(24.3)	701	(10.6)	456	(8.0)	
Medium Low	1673	(26.5)	2709	(42.2)	1363	(20.7)	464	(8.1)	
Medium High	747	(11.8)	1426	(22.2)	1966	(29.8)	1999	(35.0)	
High	347	(5.5)	727	(11.3)	2562	(38.9)	2786	(48.8)	
Procedure score									<0.001
0	5397	(85.4)	5393	(83.9)	5369	(81.4)	3789	(66.4)	
1	740	(11.7)	798	(12.4)	953	(14.5)	1008	(17.7)	
≥2	185	(2.9)	234	(3.6)	270	(4.1)	908	(15.9)	
Extended procedures, included in procedure score									
Small bowel resection	259	(4.1)	215	(3.3)	255	(3.9)	317	(5.6)	<0.001
Colon resection	377	(6.0)	409	(6.4)	535	(8.1)	696	(12.2)	<0.001
Rectosigmoid resection	348	(5.5)	412	(6.4)	407	(6.2)	868	(15.2)	<0.001
Liver resection	13	(0.2)	28	(0.4)	38	(0.6)	243	(4.3)	<0.001
Bladder resection	22	(0.3)	21	(0.3)	24	(0.4)	55	(1.0)	<0.001
Diaphragm resection	65	(1.0)	117	(1.8)	139	(2.1)	810	(14.2)	<0.001
Splenectomy	55	(0.9)	101	(1.6)	138	(2.1)	339	(5.9)	<0.001

Quartiles of annualized hospital volume were calculated at patient-level.

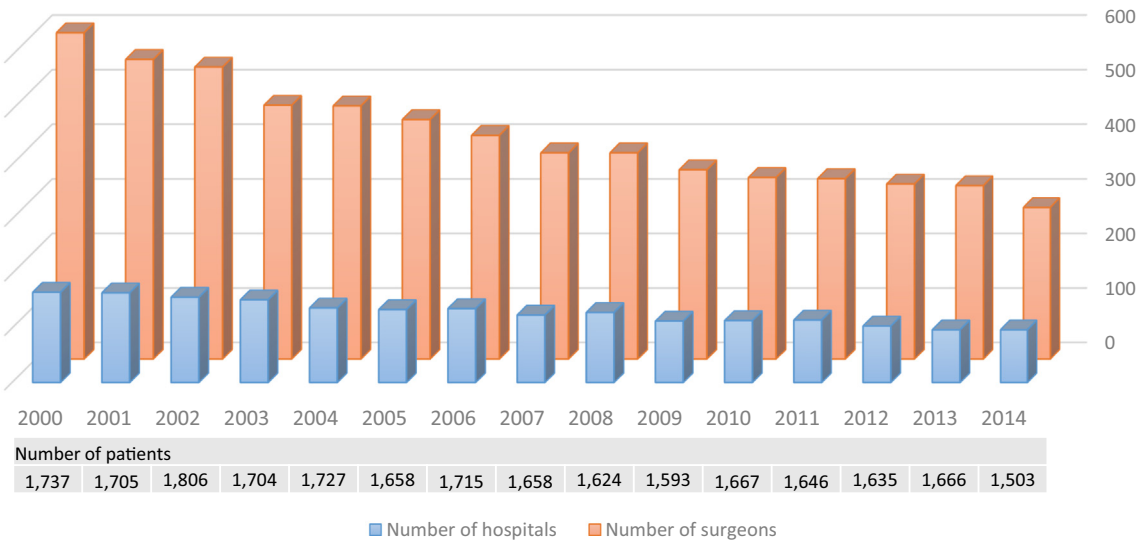

Fig. 1. Number of patients, surgeons, and hospital by year. (A) Number of patents and surgeons by year; (B) number of patients and hospitals by year.

volume quartiles decreased with increasing volume from 2.6% to 1.9%, 1.3% and 1.3%, respectively ($P < 0.001$). The corresponding adjusted risk ratio was 0.74 (95% CI, 0.55–1.001). In the multivariate models, there was a statistically significant association between increasing surgeon volume and a higher transfusion rate and lower length of stay and hospital charges.

After adjustment for clinical and demographic characteristics there was no association between hospital volume and morbidity (RR = 1.00; 95% CI, 0.88–1.15). In contrast, the mortality rate declined with volume quartile from 2.5% in the lowest volume quartile to 0.9% in the highest volume quartile ($P < 0.001$). This corresponded to a 33% decrease in mortality at high versus low volume hospitals (RR = 0.67; 95% CI, 0.46–0.97). Similar findings were noted when volume was modeled as a continuous variable (Table 4).

4. Discussion

These findings demonstrate that the surgical care of women with ovarian cancer has been concentrated to a smaller number of surgeons and hospitals over time. As a consequence, the average case volume of surgeons and centers that treat women with ovarian cancer has increased over the last decade. There was a modest association between increased surgeon and center volume and improved perioperative outcomes.

A number of studies have shown improved survival for women with ovarian cancer who are treated by specialized surgeons and centers [5,6,8,9,12,14]. In one report of over 45,000 patients, women treated at low volume centers had a 14% increase in mortality compared to those treated at high volume hospitals [6]. High volume hospitals consistently render care in accordance with national guidelines which likely explains a portion of the improved outcomes at these centers [14,27,28]. Similarly, high volume surgeons more frequently perform stage-appropriate staging and cytoreductive procedures compared to lower volume surgeons [15]. In addition to volume, provider specialty appears to play a role in outcomes, with patients treated by gynecologic oncologists having improved survival [7,29]. We noted an increase in the mean hospital and surgeon procedure volume over time in New York state.

While survival may be improved when patients are treated by high volume providers, the association between procedural volume and

Table 3
Outcomes of the ovarian cancer patients undergoing oophorectomy with or without hysterectomy by surgeon or hospital volume.

	Annualized surgeon or hospital volume								
	Low		Medium Low		Medium High		High		
	N	(%)	N	(%)	N	(%)	N	(%)	*p*-Value
Outcomes by surgeon volume									
Mortality	161	(2.6)	116	(1.9)	78	(1.3)	86	(1.3)	<0.001
Any morbidity	2003	(31.9)	2396	(38.6)	2210	(36.0)	2234	(34.8)	<0.001
Intraoperative complications	736	(11.7)	786	(12.7)	887	(14.5)	897	(14.0)	<0.001
Surgical site complications	1019	(16.2)	1249	(20.1)	1101	(17.9)	1086	(16.9)	<0.001
Medical complications	1053	(16.8)	1277	(20.6)	1055	(17.2)	1113	(17.3)	<0.001
Transfusion	2301	(36.7)	3007	(48.4)	2668	(43.5)	3047	(47.4)	<0.001
Prolonged LOS	1783	(28.4)	1638	(26.4)	1378	(22.5)	1467	(22.8)	<0.001
Excessive total charges	1502	(23.9)	1851	(29.8)	1549	(25.2)	1359	(21.2)	<0.001
Outcomes by hospital volume									
Mortality	159	(2.5)	124	(1.9)	109	(1.7)	49	(0.9)	<0.001
Any morbidity	2088	(33.0)	2435	(37.9)	2270	(34.4)	2050	(35.9)	<0.001
Intraoperative complications	724	(11.5)	806	(12.5)	847	(12.8)	929	(16.3)	<0.001
Surgical site complications	1126	(17.8)	1237	(19.3)	1091	(16.6)	1001	(17.5)	<0.001
Medical complications	1018	(16.1)	1360	(21.2)	1134	(17.2)	986	(17.3)	<0.001
Transfusion	2526	(40.0)	2817	(43.8)	2951	(44.8)	2729	(47.8)	<0.001
Prolonged LOS	1853	(29.3)	1764	(27.5)	1249	(18.9)	1400	(24.5)	<0.001
Excessive total charges	1257	(19.9)	1815	(28.2)	1382	(21.0)	1807	(31.7)	<0.001

Table 4
Adjusted risk ratios of morbidity, mortality, transfusion, prolonged LOS and excessive total charges.

	Mortality[a]	Overall morbidity	Intraoperative complications	Surgical site complications	Medical complications	Transfusion	Prolonged LOS	Excessive total charges
Surgeon volume, quartiles								
Low	Referent	Referent	Referent	Referent	Referent	Referent	Referent	Referent
Medium Low	0.85 (0.67–1.09)	1.12 (1.06–1.19)*	1.06 (0.96–1.19)	1.14 (1.06–1.24)*	1.06 (0.96–1.17)	1.19 (1.13–1.26)*	1.02 (0.95–1.09)	1.06 (0.96–1.16)
Medium High	0.64 (0.48–0.85)*	1.09 (1.01–1.17)*	1.06 (0.94–1.20)	1.12 (1.002–1.26)*	1.01 (0.92–1.10)	1.13 (1.04–1.22)*	0.95 (0.86–1.05)	0.96 (0.86–1.07)
High	0.74 (0.55–1.001)	0.99 (0.91–1.07)	0.88 (0.77–1.01)	1.04 (0.94–1.16)	1.00 (0.88–1.13)	1.10 (1.02–1.18)*	0.92 (0.85–0.99)*	0.85 (0.75–0.96)*
Surgeon volume, continuous								
1 case increase	0.995 (0.985–1.005)	1.000 (0.997–1.003)	0.998 (0.994–1.003)	1.001 (0.997–1.005)	1.001 (0.997–1.005)	1.004 (1.002–1.007)*	0.997 (0.994–0.999)*	0.996 (0.991–1.000)
5 cases increase	0.97 (0.93–1.02)	1.00 (0.99–1.02)	0.99 (0.97–1.02)	1.01 (0.99–1.03)	1.01 (0.99–1.02)	1.02 (1.01–1.04)*	0.98 (0.97–0.995)*	0.98 (0.96–1.001)
10 cases increase	0.95 (0.86–1.05)	1.00 (0.97–1.03)	0.98 (0.94–1.03)	1.01 (0.98–1.05)	1.01 (0.97–1.05)	1.05 (1.02–1.07)*	0.97 (0.95–0.99)*	0.96 (0.92–1.001)
15 cases increase	0.93 (0.80–1.08)	1.00 (0.96–1.05)	0.98 (0.91–1.05)	1.02 (0.96–1.08)	1.02 (0.96–1.08)	1.07 (1.03–1.11)*	0.95 (0.92–0.99)*	0.94 (0.88–1.002)
20 cases increase	0.90 (0.74–1.10)	1.00 (0.94–1.07)	0.97 (0.88–1.07)	1.03 (0.95–1.11)	1.02 (0.95–1.10)	1.09 (1.04–1.15)*	0.94 (0.89–0.98)*	0.92 (0.84–1.002)
Hospital volume, quartiles								
Low	Referent	Referent	Referent	Referent	Referent	Referent	Referent	Referent
Medium Low	1.13 (0.88–1.44)	1.11 (1.01–1.22)*	1.01 (0.86–1.20)	1.05 (0.92–1.20)	1.34 (1.17–1.54)*	1.08 (0.95–1.22)	1.05 (0.94–1.17)	1.29 (0.94–1.76)
Medium High	1.27 (0.97–1.68)	1.03 (0.90–1.20)	1.00 (0.79–1.27)	0.98 (0.81–1.18)	1.14 (0.94–1.39)	1.13 (0.98–1.32)	0.86 (0.67–1.09)	1.07 (0.63–1.82)
High	0.67 (0.46–0.97)*	1.00 (0.88–1.15)	1.08 (0.90–1.30)	0.97 (0.85–1.11)	1.00 (0.75–1.33)	1.19 (1.05–1.36)*	0.99 (0.81–1.22)	1.26 (0.74–2.16)
Hospital volume, continuous								
1 case increase	0.996 (0.993–0.998)*	1.000 (0.999–1.001)	1.000 (0.999–1.002)	1.000 (0.999–1.001)	1.001 (0.999–1.003)	1.001 (1.000–1.003)	1.000 (0.999–1.001)	1.003 (0.999–1.006)
5 cases increase	0.98 (0.97–0.99)*	1.001 (0.996–1.007)	1.00 (0.99–1.01)	0.999 (0.994–1.005)	1.005 (0.996–1.014)	1.01 (0.998–1.02)	1.000 (0.995–1.004)	1.01 (0.997–1.03)
10 cases increase	0.96 (0.94–0.98)*	1.00 (0.99–1.01)	1.00 (0.99–1.02)	1.00 (0.99–1.01)	1.01 (0.99–1.03)	1.01 (0.996–1.03)	1.00 (0.99–1.01)	1.03 (0.99–1.06)
15 cases increase	0.94 (0.91–0.97)*	1.00 (0.99–1.02)	1.01 (0.98–1.03)	1.00 (0.98–1.01)	1.02 (0.99–1.04)	1.02 (0.99–1.05)	1.00 (0.98–1.01)	1.04 (0.99–1.09)
20 cases increase	0.92 (0.88–0.97)*	1.01 (0.99–1.03)	1.01 (0.98–1.04)	1.00 (0.98–1.02)	1.02 (0.99–1.06)	1.03 (0.99–1.06)	1.00 (0.98–1.02)	1.05 (0.99–1.12)

For each outcome, mixed-effects log-Poisson model with robust sandwich estimation was fitted including surgeon and hospital volume quartiles, adjusting for cancer, exenteration/debulking, age, year, race/ethnicity, insurance status, admission type, comorbidity, and procedure score, accounting for hospital- and surgeon-level clustering as random intercepts. Similar models were fitted including surgeon and hospital volume as linear terms.

[a] For mortality, the mixed-effect model did not converge, therefore log binomial model not adjusting for hospital- and surgeon-level clustering was used.

* *P*-value < 0.05.

short-term perioperative outcomes for ovarian cancer has been inconsistent [11,30]. Since complete tumor resection is one of the most important prognostic factors for ovarian cancer, it is likely that higher volume surgeons and centers perform more aggressive surgical procedures. While an aggressive surgical effort may improve long term survival, these patients are at increased risk for short-term complications. One study of readmission rates after ovarian cancer-directed surgery noted a 24% higher likelihood of readmission at higher volume centers [30]. Similarly, a population-based analysis found that perioperative complication rates were higher for women with ovarian cancer treated at high volume hospitals. Notably, in this report, high volume hospitals were more proficient at managing women with complications and the perioperative mortality rate was actually lower at the high volume centers [11]. We noted that perioperative mortality was lower at high volume hospitals but neither surgeon nor hospital volume was associated with morbidity.

Over the last decade there has been interest in selected referral of patients undergoing complex procedures to specialized centers [4,31–33]. In surgical oncology, these efforts have resulted in a concentration of some high-risk procedures to selected centers and this has in turn translated into improved survival for procedures such as pancreatectomy [4]. For gynecologic cancer surgery there has also been a trend towards concentration of procedures to a smaller number of surgeons and centers [8,9,18,34]. One report from New York State found that from 2000 to 2015 the number of surgeons operating on women for endometrial cancer declined by over 60% and the mean annual surgeon volume increased three fold [34]. Similarly, for ovarian cancer surgery, efforts to regionalize care to higher volume centers have been associated with increased survival [8,9]. We noted that over the course of a 15 year period the number of hospitals treating women with ovarian cancer decreased by 40% while fewer than half as many surgeons were performing procedures in women with ovarian cancer. While we noted modest differences in short term outcomes, the impact of the shifting patterns of care for ovarian cancer may improve long-term survival.

While our study benefits from the inclusion of a large cohort of patients, we acknowledge several important limitations. First, although SPARCS has been utilized in a number of studies examining patterns of care, there may have been misclassification of a small number of surgeons or centers. Second, we used billing codes to measure complications. As such, there may have been under capture of some complications and we were only able to examine major perioperative morbidities that were most likely to generate a billing code [26]. Along the same lines, SPARCS lacks longitudinal follow-up and we

were thus unable to examine long-term outcomes including survival and quality of life. Third, SPARCS lacks data on some important characteristics that may have influenced outcome such as provider specialty and tumor characteristics and treatment such as receipt of neoadjuvant chemotherapy. Finally, the SPARCS dataset only captures care in New York State and our findings may not be generalizable to other states or regions of the U.S.

The concentration of ovarian cancer surgery has a number of important implications. Given the association between hospital and surgeon volume and survival, the trend towards regionalization of care should improve survival as has been demonstrated for other oncologic surgeries [4]. Despite improved outcomes, regionalization of care is often unpopular among patients. Some studies have found that patients prefer to receive care locally even when travel to a regional center could significantly improve survival [35]. Among patients who are willing to travel, there are often significant barriers to overcome to motivate travelling for care [36]. Further, regionalization of care often exacerbates disparities in care for socioeconomically disadvantaged patients [37,38]. Given the trends that we noted, efforts will be needed to further guide regionalization of care for ovarian cancer that balances improved outcomes with patient preferences.

Author contributions

Conception and design: all authors.
Data acquisition: Wright.
Data analysis: Wright, Chen, Buskwofie.
Manuscript drafting, revision: all authors.
Final approval: all authors.

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Dr. Wright has served as a consultant for Tesaro and Clovis Oncology. Dr. Neugut has served as a consultant to Pfizer, Teva, Otsuka, and United Biosource Corporation. He is on the scientific advisory board of EHE, Intl. No other authors have any conflicts of interest or disclosures.

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