HOSPITAL SURGICAL VOLUME AND CONCORDANCE WITH ADJUVANT CHEMOTHERAPY GUIDELINES IN OLDER ADULTS WITH CANCER

A Thesis

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of Medical Sciences

in Partial Fulfillment of the Requirements for the Degree of

Master of Science

by

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ABSTRACT

Purpose: High-volume cancer centers have repeatedly been shown to have improved survival when compared to low volume centers, and, unfortunately, a high proportion of cancer patients eligible for post-operative chemotherapy following surgical resection of non-metastatic solid tumors never receive this therapy, even though it provides a survival benefit. We hypothesized that patients who received their surgical resection at high-volume cancer centers would be more likely to receive indicated adjuvant chemotherapy than patients who received their surgical resection at low volume centers.

Methods: We identified gastric, non-small cell lung, and colon cancer patients in SEER-Medicare between 2004-2012 where their final pathological staging resulted in an NCCN recommendation to receive adjuvant chemotherapy. Patients who received neoadjuvant chemotherapy were excluded, as were patients with metastatic disease at the time of diagnosis, and we investigated the impact of hospital volume on the likelihood that a patient would have a post-discharge consultation with a medical oncologist or receive adjuvant chemotherapy.

Results: Patients with non-small cell lung and colon cancer who received their surgical resection at a high-volume institution were more likely ($p < 0.05$) to have a post-discharge consultation with a medical oncologist, though these differences disappeared when important patient-level characteristics were adjusted for. There were no differences in the rates of receiving adjuvant chemotherapy by surgical volume, yet increasing

surgical volume was associated with improved disease specific survival ($p < 0.03$ for each disease).

Discussion: Use of adjuvant chemotherapy is sub-optimal for elderly patients with gastric, non-small cell lung, and colon cancer, but is not affected by the surgical volume of their operative hospital. Survival differences between high- and low-volume hospitals cannot be explained by differences in use of adjuvant chemotherapy. Further work is needed to identify, and correct, the reasons for sub-optimal administration of adjuvant chemotherapy in eligible patients.

BIOGRAPHICAL SKETCH

Luke V. Selby, MD is a surgical resident and health services researcher. Born and raised in New York City, he attended Bates College in Lewiston, ME for his undergraduate work where he was a Deans' List student, varsity cross country and track runner, and graduated with a B.S. in Biological Chemistry. Following two years working at Massachusetts General Hospital as a research technician, he then attended medical school at New York Medical College in Valhalla, NY. Upon graduation he was awarded the *Cor et Manus* award for service to the College and he began as a categorical surgical resident at the North Shore – LIJ Health System (now Northwell Health) in Manhasset NY. He then began a three year outcomes research fellowship at Memorial Sloan Kettering Cancer Center, under the mentorship of Vivian E. M. Strong MD FACS, during which time he enrolled in the Health Policy and Economics masters program at the Weill Cornell Graduate School of Medical Sciences. He is currently finishing his surgical residency at the University of Colorado in Denver, CO, where he lives with his wife Sarah Selby, DO and their two children. He plans to pursue a career in surgical oncology and health services research.

This thesis is dedicated to my wife, Sarah T. Selby, DO. She is my best friend, my biggest supporter, and my cheerleader when I need cheerleading. This dedication, and all the thanks in the world, cannot come close to doing her justice, but I must begin somewhere.

ACKNOWLEDGEMENTS

This thesis would not have been possible without the assistance of my mentors, Elena B. Elkin, PhD and Peter B. Bach MD. Any errors in this thesis are in spite of their incredible mentoring, guidance, and patience.

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LIST OF ABBREVIATIONS

SEER: Survival, Epidemiology, and End Results

NCCN: National Comprehensive Cancer Network

CPT: Current Procedural Terminology

ICD: International Classification of Diseases

INTRODUCTION

The volume-outcome relationship in surgery is well established. Patients who receive an operation at a high-volume institution, and by a high-volume surgeon, are less likely to experience post-operative morbidity and morality that those operated on at low volume institutions or by low volume providers[1-6]. Of patients with post-operative complications, those who were operated on a high-volume center are more likely to survive than those who were not [7-10]. Finally, institutions that treat cancer more frequently have better survival than those that do not[2,3,10-16], though the reasons for these survival differences remain poorly understood. It has also been shown that high-volume hospitals are more likely to sample an appropriate number of lymph nodes during surgery, allowing proper staging and prognostication[17]. Countries that have centralized complex surgical care to a small number of selected hospitals have seen dramatic improvements in survival[18,19]. In contrast, the volume-outcome relationship does not hold when common procedures are studied[20-22], suggesting that institutional familiarity with a procedure plays an important role in providing good patient outcomes.

In the era of modern chemotherapy, surgical resection for non-metastatic solid tumors does not occur in isolation. Most solid tumors are managed in a multi-disciplinary setting, with neoadjuvant or adjuvant chemotherapy added to surgical resection depending on disease – specific indications. Unfortunately, rates of adjuvant therapy use remain sub-optimal[23], possibly contributing to decreased survival in cancer patients. The reasons for under utilization of adjuvant chemotherapy are poorly understood but include

post-operative complications[24,25], age[26,27], socioeconomic status[28,29],race[28-30], and geographic region[31], and local practice patterns[32].

The impact of provider volume on chemotherapy utilization has not been widely explored. There are suggestions that some under-utilization is driven by a lack of referral to medical oncology[32]. While surgeons are not the physician ultimately responsible for prescribing adjuvant chemotherapy, they are responsible for delivering the results of the surgical pathology, first discussing the patient's prognosis, and what (if any) further treatment the patient requires. As a result, the surgeon's knowledge of guidelines for appropriate post-operative care is paramount and could have dramatic effect on their patient's post-operative course.

To better understand whether surgical volume has an impact on the receipt of post-operative adjuvant chemotherapy, we used the Surveillance, Epidemiology, and End Results (SEER) – Medicare database to assess the relationship between institutional surgical volume and administration of adjuvant chemotherapy to patients with gastric, non-small cell lung, and colon cancer where the National Comprehensive Cancer Network (NCCN) disease – specific guidelines recommended adjuvant chemotherapy. We hypothesized that high surgical volume was associated with more frequent administration of chemo and that increased delivery of adjuvant chemotherapy contributed to improved survival.

METHODS

Data source and study population

The primary data source for our study was the SEER cancer registry data linked with Medicare claims (SEER-Medicare). This dataset is a combination of primarily collected cancer registry data from the NCI-sponsored Survey Epidemiology, and End Results survey and the linked Medicare claims for patients identified in SEER. Clinical variables in the SEER registry are collected for all patients who live in a SEER-registry area or those patients who are part of a special population, and is subsequently merged with Medicare claims for all patients 65 and older, de-identified and released with patient and hospital level information.[33] The study was deemed exempt research by the Institutional Review Board at Memorial Sloan Kettering Cancer Center, and the SEER-Medicare data were used in accordance with a Data Use Agreement from the NCI.

We identified all patients aged 66 years and older diagnosed with cancer of the lung (non small cell), gastric, and colon (excluding rectal) who had a Medicare claim for surgical resection of the primary cancer site within three months of diagnosis. Cases were identified using both Current Procedural Terminology codes (Lung: Segmentectomy: 32505, 32506, 32507, 32484, 32488, 32669, lobectomy: 32480, 32663, Pneumonectomy: 32440, 32442, 32445, 32671; Gastrectomy: 43620, 43621, 43622, 43631, 43632, 43633, 43634; Colectomy: 44140, 44141, 44143, 44144, 44145, 44146, 44147, 44160, 44204, 44205, 44206, 44207, 44208) and the 9th edition of the International Classification of Disease procedure codes (Lung: segmentectomy: 32.3, 32.30, 32.39, Lobectomy: 32.4, 32.41, 32.49, pneumonectomy: 32.5, 32.50, 32.59; Gastrectomy: 43.5, 43.6, 43.7, 43.81,

43.83, 43.91, 43.99; Colectomy: 45.61, 45.62, 45.63, 45.71, 45.72, 45.73, 45.74, 45.75, 45.76, 45.79, 45.82, 45.83, 48.61, 48.69).

Study Cohort

Patients were included if they had curative-intent surgical resection of non-metastatic lung, gastric, or colon cancer between 2004 and 2012, had continuous fee for service (Part A and B) Medicare claims throughout the study period, and had an NCCN indication for adjuvant chemotherapy based on their final surgical pathology and the disease and stage-specific guidelines from the NCCN in the year of the patient's resection. Hospital volume was estimated for individual patients as the number of organ-specific procedures performed in the 365 days preceding and including the patient's operation, and divided into terciles at the patient level. As a result of defining hospital volume at the patient level, the patient-specific volume reflects their hospital's recent experience at the time of each individual surgical resection. It is therefore possible for a given institution to be considered high volume in one procedure (based on its volume in that procedure relative to the other hospitals in the dataset) and low volume in another or to be considered low volume for one patient in our study and high-volume for another.

Patients were excluded if they had metastatic disease diagnosed prior to surgical resection, if they had prior or concurrent malignancies reported in SEER, if they were missing hospital identifiers, information on their surgical procedure or final surgical pathology, payment information, if they received neoadjuvant chemotherapy. Patients were excluded if the NCCN recommended considering chemotherapy or another

treatment modality (including observation). Patients who receive Medicare because of a diagnosis of end stage renal disease and are younger than 66 were also excluded.

Outcomes

Medical oncology visits were identified in Medicare claims within 180 days of the patient's discharge from their surgical hospitalization. Receipt of chemotherapy was also identified in Medicare claims (CPT codes 964xx, 96400-96549, Q0083-Q0085, J9000-J9999, J8520-J8999; ICD9 procedure code 99.25; ICD9 diagnosis codes: V58.1, V66.2, V67.2) within 180 days of discharge from surgical hospitalization. Overall and disease-specific survival were estimated from cause-of-death information in SEER-Medicare.

Guideline Concordance

Final surgical pathology was identified in SEER and used, in conjunction with the appropriate NCCN guidelines, to categorize the recommended post-operative care. The NCCN guidelines, which provide detailed stage-specific guidelines for disease specific screening, workup, care, and observation, are widely regarded as authoritative cancer treatment guidelines. The NCCN updates its guidelines at least yearly, and more frequently as changes in cancer care warrant. The NCCN classifies its recommendations into one of four different categories (Category 1: "Based upon high-level evidence, there is uniform NCCN consensus that the intervention is appropriate", Category 2a: "Based upon lower-level evidence, there is uniform NCCN consensus that the intervention is appropriate"; Category 2b: "Based upon lower-level evidence, there is NCCN consensus that the intervention is appropriate"; Category 3: "Based upon any level of evidence,

there is major NCCN disagreement that the intervention is appropriate"). All NCCN guideline recommendations are category 2a unless explicitly stated otherwise; for the purposes of this analysis category 3 recommendations were not evaluated and all other recommendations were considered equally.

NCCN guidelines, which are stage and disease specific, generally recommend observation (no adjuvant therapy), a clinical trial, consideration of adjuvant therapy or another treatment modality (often observation or a clinical trial), or administration of adjuvant therapy. We considered all recommendations for different chemotherapy regimens equally, and we estimated the percentage of patients who did not visit a medical oncologist post-operatively and, separately, did not receive chemotherapy.

Surgical Outcomes

We also examined early post-operative outcomes including 30-day mortality, post-operative complications, readmissions, and emergency room visits within 30 days of surgery. Using a method previously described[7,34] we used ICD9 codes available in claims data to identify post-operative acute renal failure (ICD9 code: 584) as well as cardiac (ICD 9 codes: 410.00–410.91) , pulmonary (ICD9 codes: 518.81, 518.4, 518.5, 518.8, 481, 482.0–482.9, 483, 484, 485, 507.0), thromboembolic (ICD9 codes: 415.1, 451.11, 451.19, 451.2, 451.81, 453.8), infectious (ICD9 codes: 958.3, 998.3, 998.5, 998.59, 998.51), and bleeding complications (ICD9 codes: 530.82, 531.00–531.21, 531.40, 531.41, 531.60, 531.61, 532.00–532.21, 532.40, 532.41, 532.60, 532.61, 533.00–533.21,

533.40, 533.41, 533.60, 533.61, 534.00–534.21, 534.40, 534.41, 534.60, 534.61, 535.01, 535.11, 535.21, 535.31, 535.41, 535.51, 535.61, 578.9, 998.1).

Covariates

Risk adjustment was performed using linear regression with robust standard errors to account for clustering of patients within hospitals. The covariates used for risk adjustment were patient age, sex, admission acuity, preoperative length of stay, comorbidity burden, SEER historical stage, census tract median income, marital status, SEER region, urban/rural residence, and year of surgery. Comorbidity burden was estimated using the Charlson index based on inpatient, outpatient and provider claims in the year prior to cancer diagnosis [35-37].

Statistical Methods

Our primary analysis was a time-to-event Cox model, with sensitivity analyses performed to account for differential rates of death and hospice admission observed in the different cohorts as well as exclusions for hospitals with 30-day mortality greater than 9% for colectomies, 5.5% for lung resections, and 6% for gastrectomies. A competing risk regression analyzed the effect of institution volume on both post-operative appointment with an oncologist and receipt of chemotherapy while adjusting for patient age, sex, race, marital status, income quartile, SEER region, urban/rural residence, Charlson comorbidity score, the presence of post-operative complications, and length of stay for the index hospitalization. Statistical significance was defined a $p < 0.05$, all analyses were

conducted on SAS 9.2 (SAS Institute, Cary NC) or STATA 12 (StataCorp, College Station TX).

RESULTS

The analysis included 2,431 patients who received a gastrectomy at 563 hospitals, 12,342 patients who received a lung resection at 691 hospitals, and 9,006 who received a colectomy at 1,074 hospitals (Table 1: patient characteristics, Table 2: pathological characteristics). Volume cutoffs for the low, medium, and high-volume hospitals differed by disease (Table 3).

Table 1: Patient level characteristics, by disease type, for all patients in our cohort.

	GASTRIC (n = 2,431)		**COLON (n = 12,342)**		**LUNG (n = 9,006)**	
	N	**%**	**N**	**%**	**N**	**%**
Age (Median, IQR)	76	(71 – 82)	77	(72 – 83)	74	(70 – 78)
Female Sex	1099	45	7213	58	4447	49
Married	1316	54	5960	48	5265	58
Income						
Quartile 1	600	25	3134	25	2263	25
Quartile 2	590	24	3084	25	2264	25
Quartile 3	644	26	3078	25	2252	25
Quartile 4	597	25	3046	25	2227	25
Charlson score						
Zero	1012	42	6315	51	2856	32
One	728	30	3276	27	3293	37
Two or More	691	28	2751	22	2857	32
30-Day Complication	1342	55	5330	43	5165	57

Table 2: Disease-specific pathologic characteristics for all patients in our cohort.

	GASTRIC (n = 2,431)		**COLON (n = 12,342)**		**LUNG (n = 9,006)**	
	N	**%**	**N**	**%**	**N**	**%**
T-stage						
T1	142	6	422	3	1885	21
T2	339	14	999	8	2759	31
T3	1088	45	8574	69	4118	46
T4	846	35	2345	19	244	3
Lymph Node Involvement	1710	70	12342	100	3327	37
Grade						
Well Diff	53	2	644	5	687	8
Mod Diff	634	26	7545	61	3194	35
Poorly Diff	1586	65	3461	28	4181	46
Undifferentiated	80	3	400	3	372	4
Unknown	78	3	292	2	572	6

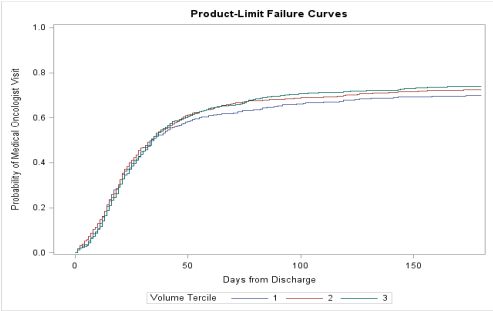
Table 3: Disease-specific cohort sizes for patients in our cohort.

	Low Volume	**Medium Volume**	**High-volume**
Gastrectomy			
# Patients	782	845	804
Surgical Volume	1 – 2 / year	3 – 5 / year	6 – 27 / year
Lung Resection			
# Patients	2,978	3,060	2,968
Surgical Volume	1 – 12 / year	13 – 30 / year	31 – 182 / year
Colectomy			
# Patients	4,136	4,090	4,166
Surgical Volume	1 – 20 / year	21 – 39 / year	40 – 143 / year

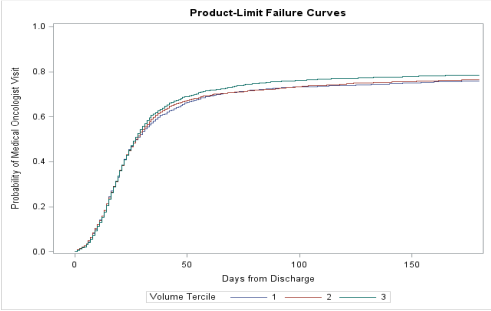
Overall, patients who had surgery at high-volume hospitals for gastric and colon cancer, but not lung cancer, were more likely to have a post-discharge visit with a medical oncologist (Figure 1). There were no differences in rates of receiving chemotherapy based on volume of a patient's operative hospital (Figure 2). Following multivariate adjustment for important patient characteristics, patients who received their colectomy at high-volume institutions were more likely to have a post-discharge visit with a medical oncologist while patients who received their lung resection at a high-volume institution were less likely to have a post-discharge visit with a medical oncologist when compared to patients at a low or medium volume institution (Table 4). Institutional surgical volume did not affect the likelihood that a patient with gastric cancer would have a post-discharge

visit with a medical oncologist, and it did not influence the likelihood that a patient, regardless of disease type, would receive adjuvant chemotherapy (Table 5).

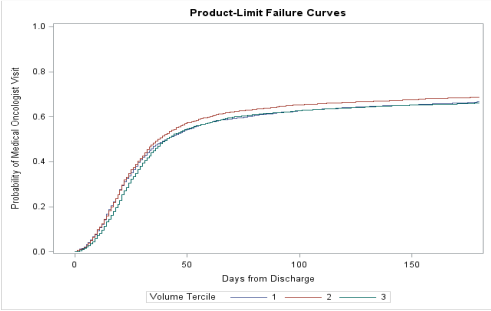
Figure 1.
Gastric:



Colon:



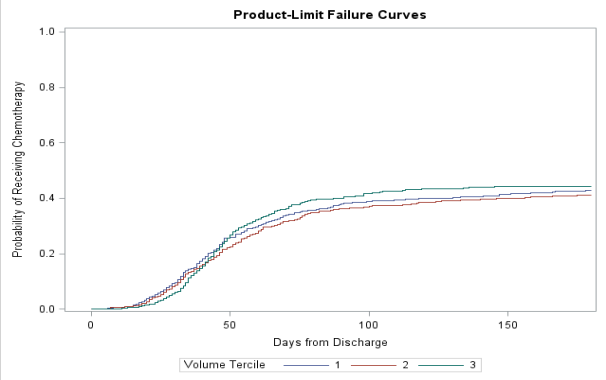
Lung:



Disease – specific time incidence of post-operative oncologist visit rates for patients who underwent curative intent resection of Gastric, Colon, or Lung cancer in SEER-Medicare between 2004 – 2012.

Figure 2:

Gastric:



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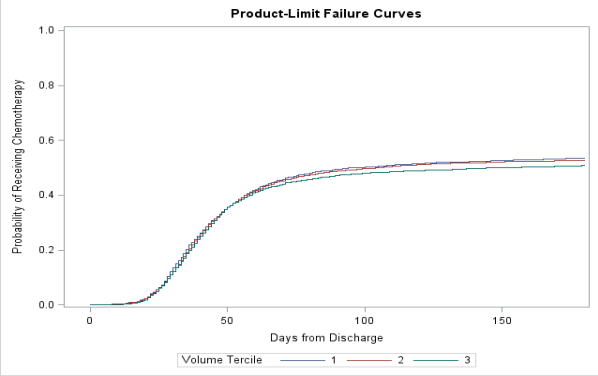
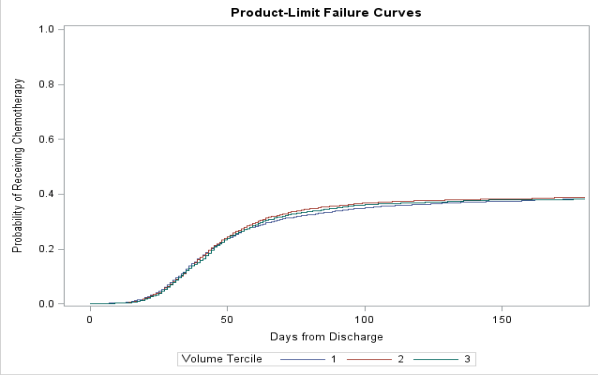


Lung:



Disease – specific time to receipt of chemotherapy for patients who underwent curative intent resection of Gastric, Colon, or Lung cancer in SEER-Medicare between 2004 – 2012.

Table 4: Adjusted impact of institutional surgical volume on the likelihood of having a post-discharge appointment with a medical oncologist.

	Gastric Cancer		Lung Cancer		Colon Cancer	
	HR	p-value	HR	p-value	HR	p-value
High-volume	1.032	0.65	1.02	0.63	1.029	0.42
70-74	1.034	0.70	0.903	0.04	1.085	0.049
75-79	0.892	0.10	0.929	0.05	0.955	0.15
80+	0.871	0.09	0.801	<.001	0.901	<.001
Male Sex	0.525	<.001	0.595	<.001	0.544	<.001
Non-white race	0.991	0.87	0.978	0.43	0.976	0.29
Not married	1.072	0.29	1.062	0.15	0.911	0.008
Marriage Unknown	0.875	0.02	0.891	<.001	0.834	<.001
Income Quartile 2	0.861	0.42	0.952	0.51	0.903	0.08
Income Quartile 3	0.94	0.38	1.013	0.76	1.042	0.20
Income Quartile 4	0.949	0.44	1.048	0.28	1.038	0.32
Midwest	0.915	0.33	1.04	0.38	1.133	0.001
South	1.217	0.07	1.236	0.001	1.21	<.001
West	0.967	0.76	0.897	0.05	1.121	0.07
Non-metro Area	0.814	0.03	0.841	0.001	0.936	0.14
Charlson Score = 1	0.748	<.001	0.922	0.05	0.869	<.001
Charlson Score = 2+	1.052	0.36	0.926	0.01	0.986	0.57
Complication	0.967	0.60	0.852	<.001	0.871	<.001
Year	0.92	0.11	0.956	0.11	0.965	0.13
Index LOS	1.029	0.01	1.058	<.001	1.02	<.001

Table 5: Adjusted impact of institutional surgical volume on the likelihood of receiving adjuvant chemotherapy.

	Gastric Cancer		Lung Cancer		Colon Cancer	
	HR	p-value	HR	p-value	HR	p-value
High-volume	0.918	0.33	1.01	0.84	0.984	0.66
70-74	0.932	0.47	0.902	0.06	0.968	0.48
75-79	0.862	0.07	0.828	<.001	0.868	<.001
80+	0.564	<.001	0.522	<.001	0.593	<.001
Male Sex	0.22	<.001	0.251	<.001	0.201	<.001
Non-white race	0.897	0.11	0.897	0.003	0.949	0.05
Not married	1.04	0.58	1.063	0.27	0.928	0.05
Marriage Unknown	0.835	0.01	0.873	<.001	0.734	<.001
Income Quartile 2	0.76	0.31	1.113	0.27	0.83	0.01
Income Quartile 3	0.977	0.82	0.967	0.52	0.936	0.09
Income Quartile 4	1.037	0.70	0.994	0.92	0.957	0.29
Midwest	1.113	0.32	1.004	0.95	0.984	0.72
South	1.251	0.10	1.011	0.90	1.066	0.30
West	0.959	0.74	0.871	0.03	0.916	0.11
Non-metro Area	0.941	0.54	0.832	0.004	0.887	0.006
Charlson Score = 1	0.871	0.26	1.026	0.64	0.857	0.002
Charlson Score = 2+	0.948	0.47	0.931	0.07	0.884	<.001
Complication	0.812	0.02	0.765	<.001	0.683	<.001
Year	0.903	0.15	0.946	0.11	0.861	<.001
Index LOS	0.971	<.001	1.042	<.001	0.963	<.001

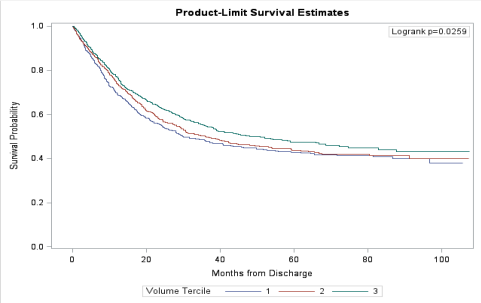
Sensitivity analyses performed to account for differential censoring due to either death or entering hospice care did not change our results, nor did excluding patients who had surgery at hospitals with very high 30-day mortality.

We did observe statistically significant differences in post-operative survival based on institutional surgical volume. For all cancer types, patients undergoing surgical resection at high-volume centers had significantly longer disease-specific survival than patients

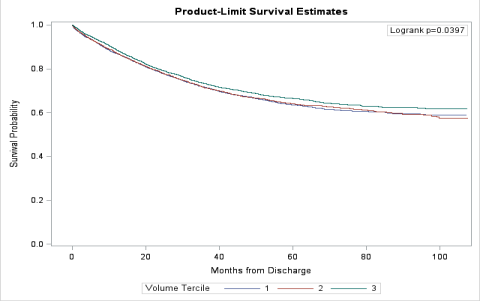
operated on elsewhere (Figure 3), and patients with either colon or lung cancer had significantly improved overall survival when operated on at a high-volume institution (Figure 4).

Figure 3:

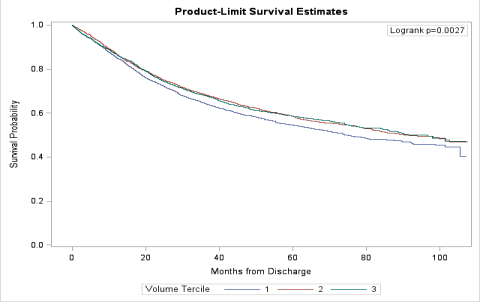
Gastric:



Colon:



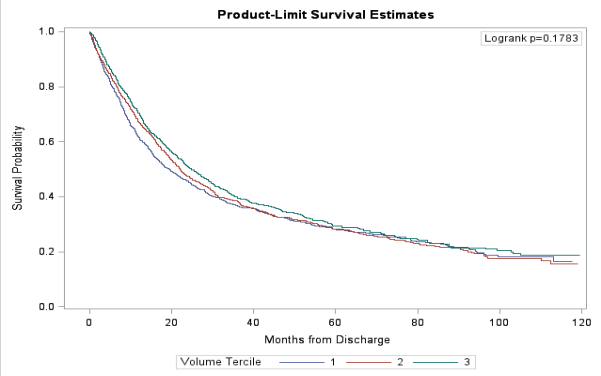
Lung:



Disease-specific survival by hospital operative volume following curative-intent resection of Gastric, Colon, or Lung cancer in SEER-Medicare between 2004 – 2012.

Figure 4:

Gastric:



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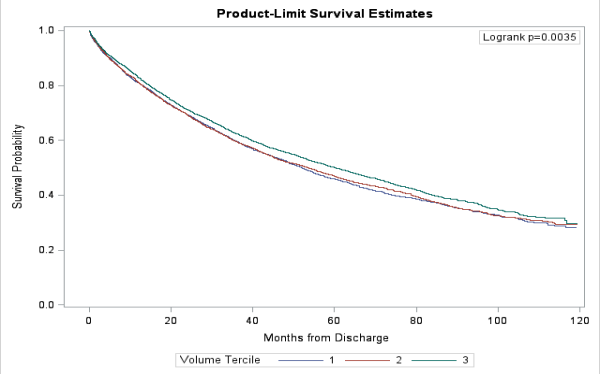
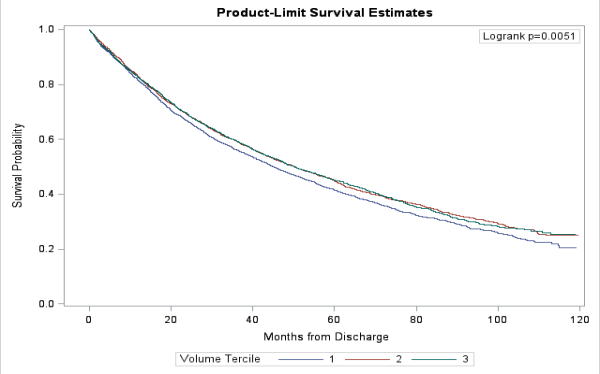


Lung:



Overall survival by hospital operative volume following curative-intent resection of Gastric, Colon, or Lung cancer in SEER-Medicare between 2004 – 2012.

DISCUSSION

In this retrospective analysis of patients with advanced non-metastatic gastric, non-small cell lung, or colon cancer in the SEER-Medicare database who received curative-intent surgical resection of gastric, lung, or colon cancer between 2004 and 2012 with advanced, non-metastatic disease, the operative volume at the institution where they received their resection did not influence the likelihood that they would receive post-operative chemotherapy. The impact of having a post-discharge visit with a medical oncologist, an important precursor to receiving chemotherapy[32], was more varied. Having surgery at a high-volume center increased the likelihood of seeing a medical oncologist in colon cancer patients, decreased the likelihood with lung cancer patients, and did not have an affect with gastric cancer. These differences disappeared when we controlled for important patient-level factors known to affect the likelihood of receiving chemotherapy.

We analyzed both the likelihood that a patient would have a post-discharge visit with a medical oncologist and the likelihood that they would receive adjuvant chemotherapy within six months of their surgical discharge because we felt that the surgeon's responsibility is to refer that patient to a medical oncologist. Receipt of adjuvant chemotherapy has repeatedly been shown to decrease recurrence and improve survival, yet it is under delivered[25,26,28,30-32]. We excluded patients who received neoadjuvant chemotherapy because we were interested in whether the surgeon, post-operatively, would refer newly diagnosed patients to a medical oncologist. In patients who receive neoadjuvant chemotherapy, regardless of who made the initial referral, the therapeutic relationship between the medical oncologist and the patient is already established.

Though we did not observe differential rates of chemotherapy receipt, we did, again observe that patients who received their surgical resection at high-volume centers have improved disease-specific (for gastric, lung, and colon cancers) and overall (for lung and colon cancers) survival compared with patients who received their surgical resection at lower volume centers. Most importantly, between 40 and 60% of patients in our study did not receive their indicated adjuvant chemotherapy. Omission of chemotherapy was associated with a number of factors, including advanced age, lower socioeconomic status, being unmarried, non-urban location, increased post-operative length of stay and higher Charlson comorbidity score (Table 5). The difference between the rates of patients with a post-operative oncologist visit and the rate of patients receiving adjuvant chemotherapy likely represents patients who, in conjunction with their medical oncologist, elected not to receive chemotherapy. We could not determine the reason patients did not receive indicated chemotherapy. For the patients who never saw a medical oncologist post-operatively, we do not know whether their surgeon recommended an appointment that they did not keep or if that essential referral was never made.

We used hospital volume instead of individual surgeon volume in order to account for the effect of casual patient care discussions that occur throughout the work day. It is possible, of course, that a surgeon may curbside consult a medical oncologist, describe a frail patient, and find out that the medical oncologist would never give that patient chemotherapy, and then the surgeon would never make that referral. Just as patients

should be party to decisions to administer chemotherapy they should be party to decisions not to administer chemotherapy.

Most of the published data investigating the impact of surgeon volume has shown that higher volume improves outcomes. The majority of this work, however, has been conducted on high-risk procedures. When low risk procedures have been studied the data has shown that volume has minimal, or no, impact on post-operative morbidity and morality[20-22]. Though we believed that the surgeon's decision to refer a patient to a medical oncologist was akin to the knowledge required to safely perform a complicated cancer resection it is possible that it is more analogous to performing a laparoscopic cholecystectomy: safer and more routine although not without infrequent complications.

The decision to administer chemotherapy is an important decision made by a medical oncologist and their patient, but we could not account for those discussions. Though the NCCN recommends that all patients in our study receive disease specific chemotherapy, there are circumstances where as an oncologist and a patient may, appropriately, agree that the risks of receiving chemotherapy outweigh the potential benefit a patient may receive. For this reason we also measured the rate at which patients have a post-discharge appointment with a medical oncologist. Even with this additional analysis we observe that between 20 and 30% of patients never meet a medical oncologist post-operatively, and therefore never have the opportunity to have this discussion.

Though we were able to tell if patients received any chemotherapy, we were not able to determine whether the regimen they received was consistent with NCCN guidelines due to the complexity of translating individual HCPCS codes (which are drug specific) to NCCN-recommended adjuvant therapy guidelines for agent, dose and frequency. We therefore assume, possibly erroneously, that all patients who received neoadjuvant chemotherapy received the correct drug regimen. Also, we only identified initial adjuvant chemotherapy. We did not attempt to determine which of our patients experienced a disease recurrence and differences in their subsequent treatment, differences in which could account for the observed survival differences.

Patients with advanced non-metastatic solid tumors are optimally treated with surgical resection and chemotherapy, both of which have independently been shown to increase survival. We hypothesized that the volume-outcome relationship in surgery, where high-volume hospitals have repeatedly been shown to out perform low volume hospitals, would hold true in post-discharge care. We believed that patients treated at high-volume hospitals would be more likely to see a medical oncologist post-operatively, would be more likely to receive adjuvant chemotherapy, and that these improvements in care would translate to improved survival. We found, instead, that there was no relationship between the volume of cancer surgery an institution performs and the likelihood that a patient treated at that hospital would receive adjuvant chemotherapy. More research must be paid to understanding the reasons for non-adherence to adjuvant chemotherapy guidelines so that more effort can be paid to improving the guidelines and their adherence.

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