Readmission rates following esophageal cancer resection are similar at regionalized and non-regionalized centers: A population-based cohort study

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ABSTRACT

Objective: Readmission following esophagectomy affects the patient experience, has important economic implications, and can be tied to hospital reimbursement. Ontario has regionalized thoracic centers; regionalized surgery may lower the readmission rate. We investigated whether surgery at regionalized thoracic centers is associated with reduced readmission following esophageal cancer resection.

Methods: A retrospective, population-based cohort study (2002-2014) was conducted in Ontario, Canada (population 13.6 million). Adults with resected esophageal cancer were identified through the Ontario Cancer Registry. Multivariable regression was used to estimate the effect of surgery at a regionalized thoracic surgery center on readmission to any Ontario hospital within 90 days following discharge.

Results: Of 3670 patients, 27.9% were readmitted within 90 days of discharge ($n = 1022$). Median hospital length of stay was 12 days (interquartile range 9-20). The readmission rate at thoracic centers was similar to other hospitals (28.1% vs 27.1%, $P = .57$). The readmission rate did not change during the 13-year study period. Case-mix adjusted readmission rates varied from 17.6% to 35.2% even across thoracic centers and were not related to hospital volume or perioperative mortality. After adjusting for confounders, we found that surgery at a thoracic center was not significantly associated with readmission (odds ratio, 1.10; 95% confidence interval, 0.95-1.27, $P = .22$).

Conclusions: Surgery at a designated thoracic surgery center did not reduce the risk of 90-day readmission following esophageal cancer resection, and readmission rates varied significantly even across thoracic centers. Our results suggest that despite universal, regionalized esophageal cancer care, there appears to be a minimum readmission threshold following esophagectomy that may be clinically necessary. (J Thorac Cardiovasc Surg 2019;158:934-42)

Graphical abstract summarizing key study characteristics and results.

Central Message

Despite universal, regionalized, high-volume esophageal cancer care in Ontario, there appears to be a minimum readmission threshold following esophagectomy that may be clinically necessary.

Perspective

Readmission following esophagectomy affects the patient experience, has important economic implications, and can be tied to hospital reimbursement. Despite universal health insurance and rigorous hospital standards for regionalized surgery in Ontario, the readmission rate was 28% at thoracic centers. For such morbid procedures, there may be a minimum clinically necessary readmission rate.

See Commentary on page 943.

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Abbreviations and Acronyms

CI	= confidence interval
EC	= esophageal cancer
ICU	= intensive care unit
LHIN	= Local Health Integration Network
OCR	= Ontario Cancer Registry
OR	= odds ratio

Scanning this QR code will take you to the article title page to access supplementary information.

Esophageal cancer (EC) carries a significant treatment burden for patients and the health care system.¹ Following curative-intent resection, patients may experience repeat hospital visits for postoperative complications as they go through the intensive process of recovery and adaptation to eating without an esophagus. The readmission rate following esophagectomy is as high as 20% by 30 days and 50% by 1 year.^{2,3} This high rate of postoperative health care use has important economic implications for health care systems. Illustratively, in the province of Ontario, Canada, EC has the greatest per-patient treatment cost among all cancers.⁴ Hospital admissions for surgery and readmissions for postoperative complications account for the majority of the cost of curative treatments.⁴ From a health policy perspective, readmission rates are now used as a quality indicator for health systems; for example, they are tied to reimbursement through the Hospital Readmissions Reduction Program in the United States, with reduced payments to hospitals with excess readmissions for conditions including acute myocardial infarction, heart failure, and pneumonia.⁵

Regionalization of surgery to subspecialized hospitals and surgeons has a well-established relationship with improved postoperative outcomes.^{6,7} Multiple factors may contribute to this relationship, including greater volumes, multidisciplinary management, and improved resources such as disease-specific postoperative pathways, specialized nursing units, and availability of advanced interventional radiology, gastroenterology, and anesthesia support. In the early 2000s, most thoracic surgery was performed in high-volume centers in Ontario. However, regionalization was formalized from 2005 to 2010, with designated centers established to improve outcomes for several high-risk and resource-intensive patient populations. Regionalization

standards were set by Cancer Care Ontario, a provincial agency mandated by the Government of Ontario to provide leadership in cancer care.⁸ Although postoperative mortality is reduced with regionalized or high-volume surgery,^{6,9-13} the effect of surgery at a regionalized center on hospital readmissions is not well explored in the literature. Furthermore, as not all jurisdictions in North America and Europe have systematically regionalized thoracic or upper gastrointestinal surgery, evidence from the Ontario experience may help clinicians and policy-makers in other regions decide whether to implement regionalization. The objective of this study is to evaluate whether surgery at regionalized thoracic centers is associated with the readmission rate following esophageal cancer resection in Ontario.

METHODS**Study Design and Setting**

We performed a retrospective, population-based cohort study of adults diagnosed with EC in Ontario, Canada (population 13.6 million). Patients were identified in the Ontario Cancer Registry (OCR). Maintained by Cancer Care Ontario, the OCR is a provincial registry of incident cancer diagnoses and captures 96% of cancer diagnoses in Ontario.^{14,15}

Ethics approval for this study was obtained from the Sunnybrook Health Sciences Centre Research Ethics Board, and we adhered to the data confidentiality and privacy policies of the Institute for Clinical Evaluative Sciences.

Study Participants

All patients with resected esophageal and gastroesophageal junction cancer diagnosed between 2002 and 2014 were identified using relevant topography, histology, and surgical codes (Table E1, Appendix E1). Patients were excluded if they were younger than 18 years of age, not eligible for government health insurance, or had a cancer type other than adenocarcinoma or squamous cell carcinoma.

Data Sources

Population-based data for this cohort were linked from the following sources (Table E2): OCR, Ontario Health Insurance Plan Database, Canadian Institute for Health Information Discharge Abstract Database, Registered Persons Database, and the 2006 Canadian Census. These datasets were linked using unique encoded identifiers and analyzed at the Institute for Clinical Evaluative Sciences.

Exposure and Outcome Definitions

The exposure of interest for this study was receipt of surgery at a Cancer Care Ontario—designated thoracic surgery center (regionalized center) or other, non-thoracic center. This was defined as a categorical variable (yes/no). The primary outcome was readmission within 90 days following discharge from the index hospital stay. Readmission to any hospital in Ontario was captured. Readmission in Ontario is defined as any patient who requires admission to the hospital from home, outpatient setting, or the emergency department for further workup or treatment and includes short stays that may be classified as “observation” and not readmission in the United States. Patients who died in the hospital before discharge were not included in the readmission analysis. Perioperative mortality (in-hospital and 90-day postdischarge mortality) across thoracic centers was included as a secondary outcome (categorical yes/no variable) to assess whether differences in this outcome may have influenced the primary outcome. Follow-up data were current to November 2016, with complete 90-day follow-up from the date of discharge for all included patients.

Covariates

The following known and available covariates were studied: age, sex, comorbidity, socioeconomic status, histology, receipt of neoadjuvant chemotherapy or radiotherapy, hospital length of stay, intensive care unit (ICU, ie, high-dependency, step-down, or intensive care unit) length of stay, major postoperative complications, discharge disposition, region of residence, and year of treatment. Age at diagnosis was used as a categorical variable based on operative risk groups: 18 to 60 years (standard risk), 61 to 70 years (moderately high risk), and ≥ 71 years (high risk). Comorbidity was measured by the sum of patients' Aggregated Diagnosis Groups using the Johns Hopkins Adjusted Clinical Groups methodology, and was categorized as low (0-4), moderate (5-9), and high (≥ 10) comorbidity.¹⁶ The median neighborhood income based on patients' postal code was used as a surrogate for socioeconomic status and was divided into quintiles based on Canadian census data.^{17,18} Histology was categorized as adenocarcinoma or squamous cell carcinoma (Table E1). Receipt of neoadjuvant chemotherapy and radiotherapy was defined as presence of at least 2 treatment visits within 180 days before surgery. Hospital length of stay indicated the total number of days the patient was admitted to hospital following surgery; interhospital transfers after surgery were considered as part of the index surgical admission. Length of stay was categorized based on the 25th and 75th percentiles into short stay (≤ 10 days), typical stay (10-20 days), and prolonged stay (≥ 21 days). ICU length of stay was categorized based on clinical judgment into typical stay (0-2 days), limited stay (3-9 days), and prolonged stay (≥ 10 days). Major postoperative complications were considered present if the patient experienced cerebrovascular accident, myocardial infarction, acute kidney injury, respiratory failure, pneumonia, airway compromise, pulmonary embolism, deep-vein thrombosis, cardiac arrest, shock, sepsis, or procedure-related complications such as bleeding. Discharge disposition following index surgical admission was a 3-level categorical variable including discharge home without community support, discharge home with support (such as home care nursing), or transfer to another facility (such as rehabilitation or continuing care). Region of residence was operationalized as the Local Health Integration Network (LHIN), where the patient lived to adjust for differences in treatment delivery across the province. LHIN is a geographic unit defined by the Province as responsible to deliver health care to the population of that region. Finally, year of treatment was included to adjust for temporal trends in patient management (categorized into 2 groups, 2002-2008 or 2009-2014).

Statistical Methods

Descriptive statistics were used to describe baseline demographics. Reasons for the first readmission within 90 days following discharge were categorized by system. Continuous data are presented with means and standard deviations and were analyzed using independent sample *t*-tests if normally distributed; non-normally distributed data are presented with medians and interquartile ranges and were analyzed using the Wilcoxon rank sum test. Categorical data are presented as frequencies and proportions; comparisons were performed using the χ^2 test. There was minimal missing data ($<1\%$).

A multivariable marginal model (generalized estimating equation) was used to estimate the independent association between surgery at a thoracic center and 90-day readmission, after adjusting for confounders and accounting for clustering at the hospital level with a compound symmetry covariance structure. Clinically informed confounders were determined a priori and adjusted in the multivariable model: age, sex, residence status, socioeconomic status, comorbidity, and era of treatment. Hospital length of stay and discharge disposition were considered mediators and not included in the model. A *P* value $<.05$ was considered statistically significant. The model was evaluated by ensuring a significant likelihood-ratio Omnibus test. Absence of multicollinearity between variables was assessed using the variance inflation factor. Model fit and overspecification were

assessed by ensuring model convergence. Influential outliers were evaluated graphically using Pearson/Deviance residuals.

The following sensitivity analyses were performed to test our assumptions: (1) we assessed the relationship between ICU length of stay and readmission as a continuous rather than categorical variable in the model, (2) we included individual year of surgery in the model (instead of 2 categories), (3) we tested the hypothesis that hospital length of stay and discharge disposition are mediators by running multivariable models with and without them included, and (4) we included major postoperative complications in the multivariable model to assess their association with readmission and effect on the relationship between surgery at a thoracic center and readmission.

All tests were 2-tailed and were performed using the SAS software application (version 9.2: SAS Institute, Cary, NC).

RESULTS

Baseline Characteristics

Of 3670 patients included in the study, 27.8% were readmitted within 90 days of hospital discharge ($n = 1022$). Average age was 64 years, 23% were female, 85% had adenocarcinoma, and median hospital length of stay was 12 days (interquartile range 9-20, Table 1). Patients treated at thoracic centers were less likely to be female, slightly less comorbid, had shorter overall hospital stay, longer ICU stay, and were more frequently discharged home with community supports compared with patients treated at non-thoracic centers (Table 1). Readmitted patients were more likely to be female, have greater baseline comorbidity burden, and longer length of hospital stay at the index admission for esophagectomy (Table 2). The overall readmission rate did not change during the 13-year study period (Figure 1). Reasons for the first readmission within 90 days following discharge are shown in Table 3.

Effect of Thoracic Surgery Centers

Most patients (76%) had surgery at a designated thoracic center; this increased from 63% in 2002 to 94% in 2014. Case-mix adjusted readmission rates varied even across designated thoracic centers, ranging from 17.6% to 35.2%, and were not related to hospital case volume or perioperative mortality (Figure 2). Complications at thoracic and non-thoracic centers are shown in Table E3. The readmission rate at thoracic centers was similar to other hospitals (28.1% vs 27.1%, $P = .57$). However, patients undergoing surgery at thoracic centers had lower perioperative mortality (9.4% vs 13.9%, $P < .001$).

Factors Associated With Readmission

Results from the multivariable marginal model identifying factors independently associated with 90-day readmission are shown in Table 4. After adjusting for covariates of interest, we found that surgery at a thoracic center was not significantly associated with 90-day readmission (odds ratio [OR], 1.10; 95% confidence interval [CI], 0.95-1.27, $P = .22$). However, female sex (OR, 1.25;

TABLE 1. Baseline demographics of the cohort

Characteristic	All patients (n = 3670)	Treated at thoracic center (n = 2777, 75.7%)	Treated at non-thoracic center (n = 893, 24.3%)	P value
Age, y, mean (standard deviation)	63.6 (11.1)	63.4 (10.9)	64.0 (11.9)	.17
Female sex	853 (23.2%)	591 (21.3%)	262 (29.3%)	<.001
Urban residence	3080 (84.1%)	2250 (81.0%)	830 (92.9%)	<.001
Income quintile				.28
(Lowest) 1	712 (19.5%)	547 (19.7%)	165 (18.5%)	
2	715 (19.6%)	534 (19.2%)	181 (20.3%)	
3	788 (21.6%)	592 (21.3%)	196 (21.9%)	
4	739 (20.3%)	551 (19.8%)	188 (21.1%)	
(Highest) 5	695 (19.1%)	533 (19.2%)	162 (18.1%)	
Adenocarcinoma	3106 (84.6%)	2333 (84.0%)	773 (86.6%)	.07
Comorbidity				.03
Low	788 (21.5%)	624 (22.5%)	164 (18.4%)	
Moderate	2019 (55.0%)	1516 (54.6%)	503 (56.3%)	
High	863 (23.5%)	637 (22.9%)	226 (25.3%)	
Neoadjuvant chemotherapy	1104 (30.1%)	989 (35.6%)	115 (12.9%)	<.001
Neoadjuvant radiotherapy	798 (21.7%)	754 (27.2%)	44 (4.9%)	<.001
Major postoperative complications	985 (26.8%)	756 (27.2%)	229 (25.6%)	.35
Hospital length of stay, d, median (IQR)	12 (9-20)	12 (9-19)	14 (10-24)	<.001
≤10	1321 (36.0%)	1086 (39.1%)	235 (26.3%)	
11-20	1433 (39.1%)	1049 (37.8%)	384 (43.0%)	
21+	916 (25.0%)	642 (23.1%)	274 (30.7%)	
ICU length of stay, d, median (IQR)	3 (0-6)	3 (0-6)	2 (0-6)	.002
0-2	1692 (46.1%)	1243 (44.8%)	449 (50.3%)	
3-7	1254 (34.2%)	992 (35.7%)	262 (29.3%)	
≥8	724 (19.7%)	542 (19.5%)	182 (20.4%)	
Discharge disposition				<.001
Home without supports	1354 (36.9%)	859 (30.9%)	495 (55.4%)	
Home with supports	2105 (57.4%)	1775 (63.9%)	330 (37.0%)	
Transfer to facility	211 (5.8%)	143 (5.1%)	68 (7.6%)	
Era of treatment				<.001
2002-2008	1909 (52.0%)	1302 (46.9%)	607 (68.0%)	
2009-2014	1761 (48.0%)	1475 (53.1%)	286 (32.0%)	

IQR, Interquartile range; ICU, intensive care unit.

95% CI, 1.12-1.39, $P < .001$) and comorbidity burden (moderate: OR, 1.51; 95% CI, 1.19-1.91, $P < .001$; high: OR, 2.28; 95% CI, 1.43-3.63, $P < .001$) were risk factors for 90-day readmission. Interestingly, age, income, rural residence, LHIN of residence, and years were not associated with risk of readmission.

Sensitivity Analyses

The results were unchanged by examining ICU length of stay as a continuous variable or including individual year of surgery in the multivariable model. Multivariable models including hospital length of stay and discharge disposition decreased the association between surgery at a thoracic center and readmission, suggesting they are mediators. Major postoperative complications were associated with increased risk of readmission (OR, 1.50; 95% CI, 1.27-1.77, $P < .001$)

and did not change the nonsignificant relationship between surgery at a thoracic center and readmission.

DISCUSSION

In this large population-based study, we found that surgery at a designated thoracic surgery center was not associated with reduced risk of 90-day readmission compared with other hospitals following regionalization of thoracic surgery in Ontario, Canada (Central Picture). The majority of previous studies assessing the volume–outcome relationship after esophagectomy have focused on perioperative mortality, or short-term outcomes such as length of stay and surgical complications.^{6,9,11-13} A 2012 meta-analysis that pooled estimates from 9 studies and more than 27,000 patients found reduced in-hospital (2.82% vs 8.48%) and 30-day mortality (0.73% vs 2.09%) at greater-volume

TABLE 2. Comparing patient characteristics by 90-day readmission status (primary outcome)

Characteristic	Not readmitted (n = 2648, 72.2%)	Readmitted (n = 1022, 27.8%)	P value
Age, y, mean (standard deviation)	63.7 (11.1)	63.4 (11.4)	.51
Female sex, (%)	584 (22.1)	269 (26.3)	.006
Urban residence, (%)	2227 (84.1)	853 (83.5)	.82
Income quintile, (%)			.38
(Lowest) 1	508 (19.2)	204 (20.0)	
2	524 (19.8)	191 (18.7)	
3	555 (21.0)	233 (22.8)	
4	524 (19.8)	215 (21.0)	
(Highest) 5	521 (19.7)	174 (17.0)	
Adenocarcinoma (vs SCC), (%)	2244 (84.7)	862 (84.3)	.76
Comorbidity, (%)			<.001
Low	609 (23.0)	179 (17.5)	
Moderate	1438 (54.3)	581 (56.8)	
High	601 (22.7)	262 (25.6)	
Neoadjuvant chemotherapy, (%)	807 (30.5)	297 (29.1)	.40
Neoadjuvant radiotherapy, (%)	580 (21.9)	218 (21.3)	.71
Major postoperative complications, (%)	653 (24.7)	332 (32.5)	<.001
Hospital length of stay, d, (%)			<.001
≤10	1002 (37.8)	319 (31.2)	
11-20	1046 (39.5)	387 (37.9)	
21+	600 (22.7)	316 (30.9)	
ICU length of stay, d, (%)			.08
0-2	1234 (46.6)	458 (44.8)	
3-7	916 (34.6)	338 (33.1)	
≥8	498 (18.8)	226 (22.1)	
Discharge disposition, (%)			.15
Home without supports	1001 (37.8)	353 (34.5)	
Home with supports	1493 (56.4)	612 (59.9)	
Transfer to facility	154 (5.8)	57 (5.6)	
Surgery at thoracic center, (%)	1997 (75.4)	780 (76.3)	.57
Era of treatment, (%)			.75
2002-2008	1373 (51.9)	536 (52.4)	
2009-2014	1275 (48.1)	486 (47.6)	

Bold indicates statistically significant values. SCC, Squamous cell carcinoma; ICU, intensive care unit.

centers.¹⁹ These studies have not looked at the impact on re-admissions, which is an important quality metric from the patient and health system perspective.

Unlike length of stay, complications, and perioperative mortality, which are outcomes focused at the patient and hospital level, readmission is also influenced by the local health system. Discharge planning, community supports, patient follow-up, delayed surgical complications, and outpatient access to the health care team all play a role in subsequent hospital readmissions. In Ontario, standards for “level 1” thoracic center designation include having 3 fellowship-trained thoracic surgeons on staff, and performing at least 20 esophagectomies and 150 lung resections per

year at the center.⁸ The hospital must have availability of an intensive care, as well as 24/7 access to the operating room, interventional radiology, diagnostic imaging, specialized nursing, laboratory, and pathology services. Furthermore, the center must have commitment to multidisciplinary care through all phases of care, including affiliation with a regional cancer center. The guidelines do not include recommendations on outpatient care and support services. Despite these rigorous hospital standards to provide high-volume and high-quality esophageal cancer care, the readmission rate was 28% at thoracic centers. Similar results were found in an analysis of lung cancer resection outcomes during regionalization in Ontario.²⁰ A Medicare analysis of

FIGURE 1. Ninety-day readmission rates following esophagectomy in Ontario by year from 2002 to 2014, adjusted for age, sex, and comorbidity. Error bars represent the 95% confidence interval. Readmission rates remained relatively stable over the 13-year study period.

increasing hospital volume for 14 cardiovascular and cancer procedures that included esophagectomy also did not find an association with 30-day readmission.²¹

One hypothesis is that for such a highly-morbid procedure, there is a minimum readmission rate that patients and physicians must accept as part of the risk of surgery. Indeed, there are data to support this possibility. For example, despite advances in nutrition support, perioperative care, and the introduction of minimally invasive surgical techniques, reported readmission rates after esophagectomy have remain relatively constant over the last decade.²²⁻²⁶ Importantly, if a minimal amount of readmissions occur with a major operation such as esophagectomy, decisions to financially penalize the institution may not be warranted, as some readmissions may be unavoidable.

Ontario has a universal, single-payer health system. Theoretically, this reduces care fragmentation since interfacility transfers, outpatient care, and specialist follow-up can be organized as necessary for patients without worry for insurance systems and reimbursement. Furthermore, there are

no financial penalties for hospital readmissions, such as in the US Hospital Readmissions Reduction Program, allowing the discharge decision to be focused on clinical criteria without fear of potential readmission costs for the discharging hospital. Both characteristics should have allowed Ontario to realize the benefits of regionalization on readmission after esophagectomy. Finding no impact on the readmission rate with regionalization speaks strongly to the idea of a minimum expected and accepted readmission rate for high-risk procedures, described by others as a “readmission floor.”^{27,28} Tellingly, the 3 greatest-volume thoracic centers in Ontario all had a readmission rate greater than 25%. An analysis of the American College of Surgeons National Quality Improvement Program in 2018 showed that surgical complications drive readmission following esophagectomy.² In this setting, readmission and rescue is a clinically necessary priority to ensure a good outcome. Financial penalty for all readmissions, without appreciating a certain percentage of unpreventable readmissions for surgical patients, may place unreasonable expectations of a perfect outcome on patients, surgeons, and hospitals in jurisdictions where such penalties are imposed. Although there is currently no health policy that specifically monitors or penalizes readmission after esophagectomy, data from our study will be necessary for policymakers to consider before such measures are proposed.

Importantly, even among these specialized centers, the readmission rate varied from 17.6% to 35.2%. As this variation does not appear to be related to volume, next steps should include examination of the processes of care and pathways that are used at the low-readmission hospitals, to create similar programs at the greater readmission hospitals. Efforts to improve the readmission rate will also need to focus outside hospitals, and include local health system changes, to help patients with preventable readmissions be treated out of hospital. Of note, readmission rates in our study may appear “high” due to complete capture through administrative data in Ontario. Our data captured

TABLE 3. Categories of reasons for the first readmission within 90 days following esophagectomy discharge

Reason for readmission	Number (%)
Gastrointestinal	305 (27.3)
Respiratory	187 (16.8)
Cardiovascular	110 (9.9)
Cancer-related	103 (9.2)
Postoperative complication	88 (7.9)
Infection	52 (4.7)
Endocrine	44 (3.9)
Genitourinary	34 (3.1)
Psychiatric or neurologic	24 (2.2)
Pain	24 (2.2)
Hematologic	22 (2.0)
Other	141 (12.6)

FIGURE 2. Ninety-day readmission and in-hospital/90-day mortality rates at non-thoracic centers, compared with thoracic centers, following esophagectomy in Ontario. Rates are adjusted for case mix (age, sex, comorbidity, rural residence, income quintile, and year), and *error bars* represent the 95% confidence interval. Thoracic centers are ordered from highest volume (1) to lowest volume (15). Readmission rates varied across thoracic centers, and were not related to hospital volume or in-hospital/90-day mortality.

all readmissions to any hospital in the province, including to index and non-index hospitals, and we believe this is an accurate estimation of the true readmission rate after esophagectomy.

This study reveals some further interesting findings with regard to regionalized care. More patients achieved hospital discharge within 10 days at thoracic centers (39.1% at thoracic vs 26.3% at non-thoracic centers), while achieving the same readmission rate. This likely represents the trend toward decreased hospital stays over time but may also be the result of improved multidisciplinary care at regionalized centers, including specialized nursing, dietetics, and physiotherapy care, and protocolled care developed through center expertise. Furthermore, regionalized centers may have greater resources to rescue deteriorating patients. This hypothesis is supported by the increased ICU care we observed at thoracic centers. Although the proportion of patients requiring greater than 7 days of ICU care was similar at thoracic and non-thoracic centers (19.5% vs 20.4%, respectively), the proportion of patients requiring between 3 and 7 days of ICU care was 35.7% in the thoracic center group and 29.3% in the non-thoracic center group. We also observed that patients at thoracic centers received increased outpatient supports. Although changes in outpatient care were not part of Cancer Care Ontario's regionalization strategy, this may have occurred either through a change in the local delivery of care across Ontario's health administration regions (LHINs), or because of a greater recognition by specialized centers for the need to connect patients with homecare services. This also resulted in a small decrease

in the number of patients requiring transfer to a rehabilitation facility after the index surgical admission in the thoracic center group.

Although not the primary objective, our study uncovered 2 important sex differences in patients undergoing esophagectomy. First, female patients were less likely to be treated at a thoracic center. Sex-related disparities in referral for specialist cancer care has been reported in other studies.²⁹⁻³² It is unclear whether this is due to provider bias causing lack of referral or driven by patient choice. For example, among patients randomized to screening for colorectal cancer in the United Kingdom, part of the reason women were less likely to be screened was explained by different attitudes and preferences for care.³³ Second, female sex was associated with increased risk of readmission, a finding that has been observed in the cardiac literature after myocardial infarction and percutaneous coronary intervention.^{34,35} Possible explanation includes the fact that women are more likely to be the caregiver and less likely to have support at home, thus increasing their chances of presenting to hospital when a concern arises postoperatively. Further examination of factors leading to increased readmission for women is necessary to develop support mechanisms to prevent these visits.

There are limitations to note in this study. The analysis does not include cancer stage. Greater-stage patients are more likely to have greater weight loss at presentation, poor performance status, and experience complications, all of which could increase the risk of readmission. Since greater-stage patients are more likely to be referred to a

TABLE 4. Multivariable analysis for predictors of 90-day readmission following esophagectomy

Predictor	Odds ratio (95% confidence interval)	P value
Surgery at thoracic center	1.10 (0.95-1.27)	.22
Age, y		.17
18-60	(Ref)	
61-70	0.89 (0.77-1.05)	
71+	0.81 (0.60-1.10)	
Sex		<.001
Male	(Ref)	
Female	1.25 (1.12-1.39)	
Residence status		.91
Urban residence	(Ref)	
Rural residence	1.01 (0.84-1.21)	
Income quintile		.51
(Lowest) 1	(Ref)	
2	0.93 (0.74-1.16)	
3	0.86 (0.54-1.36)	
4	0.79 (0.40-1.58)	
(Highest) 5	0.74 (0.29-1.84)	
Comorbidity		<.001
Low	(Ref)	
Moderate	1.51 (1.19-1.91)	
High	2.28 (1.43-3.63)	
Era of treatment		.65
2002-2008	(Ref)	
2009-2014	1.03 (0.90-1.18)	

Results are adjusted for Local Health Integration Network of residence, which was not a significant predictor of readmission ($P = .08$), omnibus likelihood ratio test $P < .001$, Hosmer–Lemeshow test $P = .78$, c-statistic = 0.595. Bold indicates statistically significant values.

thoracic center, not accounting for this may contribute to some residual confounding in the model and explain the lack of difference seen in readmissions at thoracic versus non-thoracic centers. Another consideration is that defining postoperative complications with granularity, in the format suggested by the international Esophageal Complications Consensus Group, is challenging with administrative data studies.³⁶ We followed the methodology of other database studies in categorizing complications by system.^{2,20,37,38}

In summary, this study found a 27.7% 90-day readmission rate following resection for esophageal cancer. Readmission rates varied significantly even across designated thoracic surgery centers. Surgery at a thoracic center did not reduce the risk of readmission. These results are summarized in Figure 3. Our results suggest that despite universal, regionalized, high-volume esophageal cancer care, there is a minimum readmission threshold following esophagectomy that may be clinically necessary. Further work will need to focus beyond hospital-level changes and include local health system changes to improve out-of-hospital care and reduce preventable readmissions.

90-Day Readmission Following Esophagectomy at Regionalized and Non-Regionalized Centres

There appears to be a minimum readmission threshold following esophagectomy & may be clinically necessary

FIGURE 3. Graphical abstract summarizing key study characteristics and results. Ninety-day readmission rates following esophagectomy in Ontario remained relatively stable from 2002 to 2014, were similar at thoracic and non-thoracic centres, and varied from 18% to 35% even at thoracic centers. There appears to be a minimum readmission threshold following esophagectomy and may be clinically necessary.

Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

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Key Words: esophageal cancer, esophagectomy, regionalization, readmission

APPENDIX E1

International Classification of Diseases for Oncology, Third Edition (ICD-O-3) topography codes used to define esophageal and gastroesophageal junction cancer: C15.0-C15.9, C16.0-C16.2, C16.5, C16.8, and C16.9. Surgical resection was defined using the Canadian Classification of Health Interventions (CCI) codes for esophagectomy or gastrectomy (CCI codes 1.NA.87-92.^ and 1.NF.89-90.^).³⁷

THOR

TABLE E1. ICD-O-3 morphology codes used to define adenocarcinoma and squamous cell carcinoma

Adenocarcinoma	Squamous cell carcinoma
81403, 81413, 81423, 81433, 81443, 81453, 82003, 82103, 82113, 82143, 82503, 82553, 82603, 82613, 82623, 82633, 82903, 83103, 83233, 83803, 84013, 84603, 84803, 84813, 84823, 84903, 85003, 85423, 85703, 85723, 85743, 85763.	80513, 80523, 80703, 80713, 80723, 80743, 80763, 80833, 85603, 89803.

TABLE E2. Data sources for the study

Database	Information
Ontario Cancer Registry	Cancer information, including histology
Ontario Health Insurance Plan Database	Inpatient and outpatient physician billing data; includes information on diagnoses and services provided
Canadian Institute for Health Information Discharge Abstract Database (CIHI-DAD)	Information from hospital admissions, including diagnoses and receipt of esophagectomy or gastrectomy; mandatory reporting system for all institutions in Ontario
Registered Persons Database (RPDB)	Derived from all administrative data sources and provides demographic data, vital status, and details such as date of last contact with the health care system
2006 Canadian Census	Demographic information including median neighborhood income quintile

TABLE E3. Proportion of patients experiencing major postoperative complications, stratified by surgery at a thoracic or non-thoracic center

Complication	Treated at thoracic center (n = 2777, 75.7%)	Treated at non-thoracic center (n = 893, 24.3%)	P value
Cerebrovascular accident, (%)	14 (0.5)	≤5 (0.4)	.83
Myocardial infarction, (%)	57 (2.1)	25 (2.8)	.19
Acute kidney injury, (%)	69 (2.5)	18 (2.0)	.42
Respiratory failure, (%)	474 (17.1)	134 (15.0)	.15
Pneumonia, (%)	117 (4.2)	38 (4.3)	.96
Airway compromise, (%)	63 (2.3)	7 (0.8)	.005
Procedure-related, (%)	170 (6.1)	56 (6.3)	.87
Pulmonary embolism, (%)	15 (0.5)	10 (1.1)	.07
Deep-vein thrombosis, (%)	24 (0.9)	9 (1.0)	.69
Cardiac arrest, (%)	19 (0.7)	11 (1.2)	.11
Shock, (%)	27 (1.0)	≤5 (0.4)	.14
Sepsis, (%)	47 (1.7)	16 (1.8)	.84