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ORIGINAL ARTICLE

Economic impacts of care by high-volume providers for non-curative esophagogastric cancer: a population-based analysis

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Abstract

Background Esophagogastric cancer (EGC) is one of the deadliest and costliest malignancies to treat. Care by high-volume providers can provide better outcomes for patients with EGC. Cost implications of volume-based cancer care are unclear. We examined the cost-effectiveness of care by high-volume medical oncology providers for non-curative management of EGC.

Methods We conducted a population-based cohort study of non-curative EGC over 2005–2017 by linking administrative datasets. High-volume was defined as ≥ 11 patients/provider/year. Healthcare costs ($USD/patient/month-survived) were computed from diagnosis to death or end of follow-up from the perspective of the healthcare system. Multivariable quantile regression examined the association between care by high-volume providers and costs. Sensitivity analyses were conducted by varying costing horizons and high-volume definitions.

Results Among 7011 non-curative EGC patients, median overall survival was superior with care by high-volume providers with 7.0 (IQR 3.3–13.3) compared to 5.9 (IQR 2.6–12.1) months ($p < 0.001$) for low-volume providers. Median costs/patient/month-lived were lower for high-volume providers ($5518 vs. $5911; $p < 0.001$), owing to lower inpatient acute care costs, despite higher medication-associated and radiotherapy costs. Care by high-volume providers was independently associated with a reduction of $599 per patient/month-lived (95% confidence interval − 966 to − 331) compared to low-volume providers. The incremental cost-effectiveness ratio was − 393. Care by high-volume providers remained the dominant strategy when varying the costing horizon and the high-volume definition.

Conclusion Care by high-volume providers for non-curative EGC is associated with superior survival and lower healthcare costs, indicating a dominant strategy that may provide an opportunity to improve cost-effectiveness of care delivery.

Keywords Outcomes · Costs · Cancer · Volume · Esophageal · Gastric

Introduction

Cancer care is increasingly complex and there can be variation in patterns of care and outcomes across institutions and providers. A growing number of studies have examined the relationship between clinical volume and outcomes in surgical cancer care and have influenced health policy toward provision of care by high-volume providers [1-3]. Whether clinical volume also plays a role in the delivery of medical cancer care is less clear and the need for such information has been highlighted [4]. Recent data indicated improved survival for solid malignancies with care by high-volume medical oncologists [5-7].

As healthcare costs increase, it is important to better understand how the organization and provision of care relate to both patient outcomes and healthcare expenses. The

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relationships between clinical volumes, cancer outcomes, and cost remain largely unknown [8]. With current cost and resource constraints, it is ever more critical to consider costs in the development of health policy. However, data on the effect of specialization or volume on costs in cancer care is scarce [9].

Esophagogastric cancer (EGC) is both highly fatal and one of the most expensive cancers to treat on a per-patient basis [10-13]. Care by high-volume providers has recently been independently associated with superior overall survival for EGC patients (hazard ratio—HR 0.89; 95% confidence interval—95%CI 0.84–0.93) [6]. However, specialized care by high-volume providers is also associated with increased use of therapy and may be more resource-intensive and costly; the economic impact of such care is unknown.

Thus, we conducted a population-based costing analysis to examine the cost-effectiveness of care by high-volume providers compared to low-volume providers for the non-curative management of EGC.

Methods

Study design and data sources

Using linked administrative databases stored at ICES in Ontario, Canada, we conducted a population-based analysis to examine the impact of provider-volume and outcomes on cost, from the healthcare system perspective, over the patient's lifetime following EGC diagnosis. The Ontario population benefits from universally accessible and publicly funded health care through Ontario Health Insurance Plan (OHIP) [14].

The study was approved by the Sunnybrook Health Sciences Centre Research Ethics Board. It was conducted and reported following the REporting of studies Conducted using Observational Routinely collected Data (RECORD) statement and the ISPOR Consolidated Health Economic Evaluation Reporting Standards (CHEERS) [15, 16].

We used population-based healthcare and administrative registries in Ontario as previously been reported and detailed in Supplementary Table 1 [17, 18]. The datasets were linked using unique Identification Key Number (IKN) for each patient.

Study population and cohort

This study was conducted in all patients with a new diagnosis of esophageal or gastric adenocarcinoma or squamous-cell carcinoma from January 1st, 2005 to March 31st, 2017 identified who did not undergo curative-intent therapy and had ≥ 1 encounter with medical oncology, using a strategy previously described (Supplementary Table 2) [6].

Exposure

The exposure of interest was care by a high-volume medical oncology provider, defined as the 4th and 5th quintile of provider volume and set at ≥ 11 patients per provider per year, as previously described (Supplementary Table 3) [6].

Outcomes measures

We used a bottom-up approach to determine patient-level costs. Costs were computed using: (1) disaggregated general healthcare costs, and cancer-specific costing for (2) medication-associated costs (including systemic therapy) and (3) radiotherapy costs [19-21]. Median cost per patient per month-survived were computed as adjusted 2018 CAD and converted to 2018 USD. A conversion of 1 Canadian dollar to 0.72 US dollars was applied, as per the Bank of Canada's rate in 2018. Median costs were analyzed to avoid skewing the measure of central tendency with outliers.

For general healthcare costs, person-level costs were generated using resources for inpatient acute care, ambulatory care, emergency services, prescription drugs, physician claims, inpatient rehabilitation, complex continuing care and long-term care, home care services, admissions to mental health beds, and the assisted device program, for all patients seen by medical oncology providers. For hospital-based encounters, costs are calculated by multiplying resource intensity weight (RIW) for the specific encounter by an annual cost-per-weighted-case to generate the total cost for an encounter [22]. RIWs are annual numerical index values calculated based on the relative costs of treatments for specific patient demographics. For longer-term episodes of care, such as complex continuing care, costs were determined by weighted-days. For claims/visit-based encounters, costs were determined at utilization.

Medication-associated costs were determined using drug-specific patient visit and cost information [23]. Radiotherapy costs encompassed all costs for treatment, planning, and operational. Overhead costs that cannot be attributed to a specific patient or visit, such as equipment and medical physicist costs, were estimated separately to get a per-visit cost.

Survival was measured from date of diagnosis to the date of death according to the RPDB, with patients censored at the date of last contact or end of study date.

Covariates

Age and sex were obtained from the RPDB. Rural living was determined with postal code of residence [24]. Income quintile was assessed with an ecologic measure based on the median income of a patient's postal code of residence using national census data [25, 26]. The comorbidity burden was measured using the Elixhauser comorbidity index with a 2-year look-back window and dichotomized with a cut-off of 4 for high comorbidity burden [27, 28]. Cancer type was dichotomized as esophageal or gastric. Receipt of chemotherapy was defined by identifying patients with at least two chemotherapy infusions billed from the date of diagnosis to end of follow-up [29-31].

Statistical analysis

Categorical variables were described as absolute number (*n*) and proportion (%) and continuous variables as median with inter-quartile range (IQR). Comparison was undertaken with Chi square test for categorical variables, and the Kruskal–Wallis test for continuous variables. Median survival with 95% confidence interval (95%CI) was computed using Kaplan–Meier methods and compared between groups with the log-rank test [32].

To examine potential drivers of the cost difference between groups, we computed the absolute difference in total cost per patient per month-survived between high and low-volume providers groups, for each cost-category. We computed incremental cost effectiveness ratio (ICER), by dividing the difference in median costs per patient per month-survived by the difference in median survival between high and low-volume providers groups.

Multivariable regression models were constructed to assess the association between care by high-volume provider and overall median cost per patient per month-survived. Relevant demographic and clinical characteristics were identified a priori as potential confounders of the relationship between provider-volume and outcomes. The variables were selected based on clinical relevance and existing literature [33]: age (categorical), sex, comorbidity burden, income, rural living, time period of diagnosis (2005–2010 vs. 2011–2017), and type of cancer (esophageal vs. gastric). Quantile regression of the median cost per patient per month-survived was used and results reported as effect estimate with 95% confidence interval (95%CI).

Sensitivity analysis

We conducted sensitivity analyses to assess the robustness of the results. First, we varied the time horizon to capture costs to ascertain whether differences in costs and cost-effectiveness varied with increasing time from diagnosis: costs were computed for the first 3, 6, and 9 months following date of diagnosis. The number of patients included in each analysis varied depending on length of follow-up. Second, we varied the definition of high-volume providers: costs and median survival were computed using the second (≥ 6), third (≥ 8), and fifth (≥ 15) quintiles of provider-volume [6].

Statistical significance was set at $p \leq 0.05$. All analyses were conducted using SAS Enterprise Guide 6.1 (SAS Institute, Cary, NC, USA).

Results

A total of 7011 patients were identified with a new diagnosis of EGC, who did not receive curative-intent surgery or chemoradiation therapy and had a medical oncology

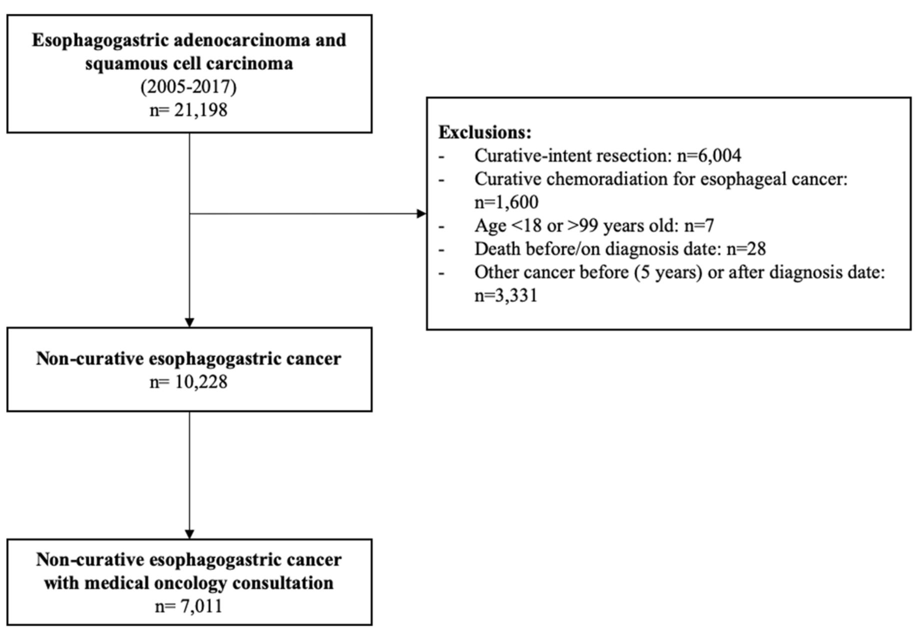

Fig. 1 Flow diagram of cohort creation

consultation (Fig. 1). Characteristics of included patients are presented in Table 1. Median follow-up was 6.3 (IQR 1.9–11.9) months. High-volume providers (≥ 11 patients/provider/year) cared for 2,518 (35.9%) patients. Patients cared for by high-volume providers were more likely to receive chemotherapy, with 50.8% compared to 44.9% for low-volume providers ($p < 0.001$). Median survival was 7.0 (IQR 3.3–13.3) months for high-volume providers compared to 5.9 (IQR 2.6–12.1) months for low-volume providers ($p < 0.001$).

Median costs/patient/month-survived are detailed in Table 2, for each cost category. Total median cost/patient/month-survived was lower for high-volume providers than for low-volume providers, with 7,456 USD (IQR 4325–12,564) compared to 7987 USD (IQR 4435–15,100). The ICER for high-volume providers in the main analysis was − 393, indicating that for each patient cared for by a high-volume provider, there was a cost-saving of 393 USD per month-survived. This showed a dominant strategy. The examination of absolute differences in total costs/patient/month-survived by cost category is presented in Fig. 2. While cancer treatment costs related to radiotherapy and medications were higher for high-volume providers, lower inpatient acute care costs drove the overall cost savings.

After adjusting for age, sex, comorbidity burden, income quintile, rural residence, cancer type, and time period of diagnosis, care by high-volume providers was still associated with lower costs compared to low-volume providers (effect estimate − 599; 95%CI − 866 to − 331).

With regards to sensitivity analyses, changes in time horizon modified the absolute difference in median costs per patient per month-survived between high and low-volume providers, but not its direction, with − 716 USD for 3-month, -642 USD for 6-month, and − 543 USD for 9-month time horizons. The incremental costs and survival benefits when varying the definition of high-volume providers are depicted in Fig. 3. Care by high-volume providers remained the dominant strategy for all definitions. The cut-off of ≥ 11 patients/provider/year (4th quintile) presented the largest gain in survival for the reduction in cost.

Table 1 Characteristics of patients with non-curative management of esophagogastric cancer, stratified by receipt of care by low and high-volume providers

Variable	Low-volume providers (< 11 patients/year) $n = 4493$	High-volume providers (≥ 11 patients/year) $n = 2518$	p-value
Cancer type			
Esophageal	1423 (31.7%)	997 (39.6%)	< 0.001
Gastric	3070 (68.3%)	1521 (60.4%)	
Age (years old)			
≤ 60	1187 (26.4%)	794 (31.5%)	< 0.001
61–70	1156 (25.7%)	699 (27.8%)	
71–80	1213 (27.0%)	643 (25.5%)	
≥ 81	937 (20.9%)	382 (15.2%)	
Female sex	1496 (33.3%)	689 (27.4%)	< 0.001
High comorbidity burden (Elixhauser index ≥ 4)	480 (10.7%)	246 (9.8%)	0.23
Rural residence	592 (13.2%)	326 (12.9%)	0.89
Income quintile			
1st (lowest)	946 (21.1%)	509 (20.2%)	0.16
2nd	993 (22.1%)	521 (20.7%)	
3rd	908 (20.2%)	526 (20.9%)	
4th	869 (19.3%)	499 (19.8%)	
5th (highest)	777 (17.3%)	463 (18.4%)	
Time period of diagnosis			
2005–2011	2190 (48.7%)	1113 (44.2%)	< 0.001
2012–2017	2303 (51.3%)	1405 (55.8%)	

Values are n (%) representing column percentages

Discussion

In this population-based economic analysis, we examined the costs of care by high-volume (≥ 11 patients/provider/year) providers which led to both longer survival and lower healthcare costs, with an ICER of − 393 indicating a dominant strategy, for non-curative EGC. It was independently associated with reduction in median cost per patient per month-survived. The direction of the cost difference persisted with changes in time horizons and the finding of dominant strategy was robust to variations in high volume definition.

Higher clinical volume has recently been associated with superior survival for medical oncology care [34-38]. From policy and system perspectives, it is important to consider healthcare costs along with outcomes when looking at feasibility of changes in care organization [9, 11]. Prior economic analyses of EGC care focused on comparing therapeutic regimens [11, 39-42]. Analyses examining healthcare costs in relation to clinical volume have been limited to surgical care, single care episodes, in-hospital costs, and short time-horizon of maximum 12 months [12, 33, 43-45]. The most comprehensive analysis of the economics of medical oncology volume-based management did not include community, ambulatory, or home-based care, was limited in time horizon, included patients treated with curative and non-curative intents, and did not relate costs to patient outcomes [46]. Herein, we leveraged unique comprehensive and complete healthcare data for an entire population under a single-payer system to analyze the cost-effectiveness of provider-volume in medical cancer care for non-curative EGC.

Despite higher therapy costs for high-volume providers, the lower use of inpatient services combined with survival

Table 2 Median costs/patient/month-survived for non-curative esophagogastric cancer, stratified by receipt of care by low and high-volume providers

Cost category	Low-volume providers (< 11 patients/year) Median cost (IQR)—USD	High-volume providers (≥ 11 patients/year) Median cost (IQR)—USD	*p* value
Radiotherapy costs	36 (0–514)	63 (0–612)	< 0.001
Medication-associated costs	47 (5–304)	85 (14–486)	< 0.001
General healthcare costs			
Outpatient care	270 (85–592)	283 (111–547)	0.21
Ambulatory surgery	47 (0–138)	63 (0–153)	< 0.001
Emergency department	106 (102–252)	108 (30–222)	0.43
Dialysis costs	0 (0–0)	0 (0–0)	–
Outpatient cancer care*	91 (0–728)	199 (0–777)	< 0.001
Inpatient care	2089 (646–7849)	1607 (490–5731)	< 0.001
Rehabilitation	0 (0–0)	0 (0–0)	–
Complex continuing care	0 (0–0)	0 (0–0)	–
Long-term care	0 (0–0)	0 (0–0)	–
Home care services	283 (46–637)	325 (95–668)	< 0.001
Inpatient mental health	0 (0–0)	0 (0–0)	0.93
Physician billings*	780 (467–1387)	732 (475–1192)	0.001
Total—general healthcare	5114 (2648–10,447)	4429 (2484–8028)	< 0.001
Total costs	5910 (3282–11,174)	5518 (3201–9297)	< 0.001

IQR Inter-quartile range, *USD* US dollars

*Excluding radiotherapy visits (included in radiotherapy costs)

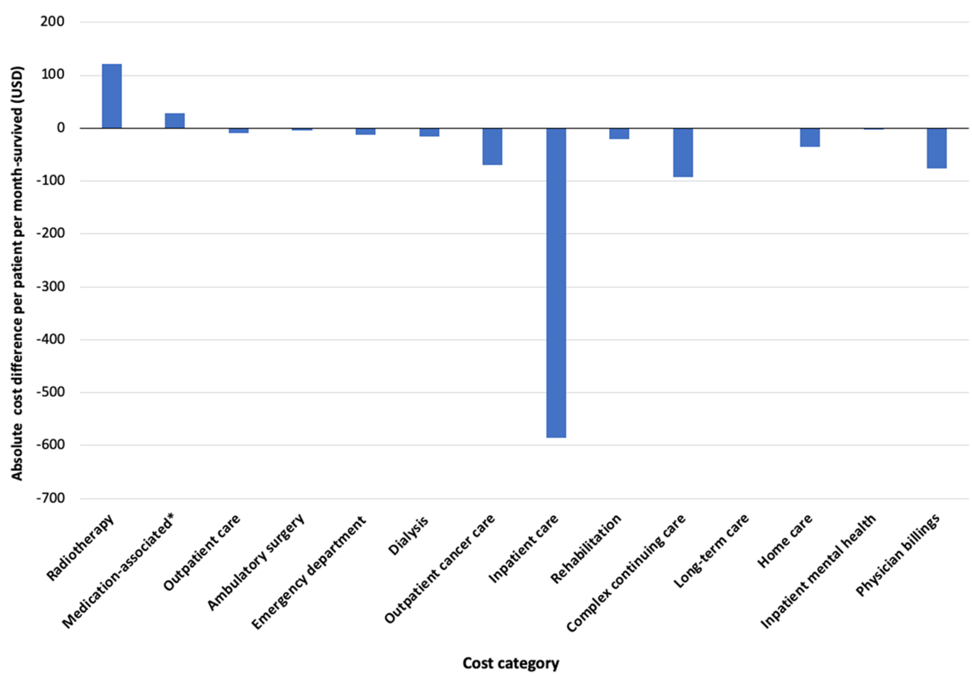

Fig. 2 Absolute difference in total costs/patient/month-survived between high- and low-volume providers, stratified by cost category. *including systemic therapy and supportive drugs

benefit led to a significant reduction in cost per patient per month-survived. Specialized cancer care has been associated with higher rates of therapy and reduced costs for investigations and hospitalizations [12, 33, 43-45]. Population-based data previously revealed decreased cumulative hospital stays and use of homecare services with higher-volume physicians for metastatic gastric cancer, but did not relate those findings to patient outcomes or healthcare costs [47]. High use of inpatient care may be appropriate when facing sick or complex patients. However, it may not be appropriate when it can be avoided by providing therapy that improves symptom patterns and delays clinical deterioration while increasing

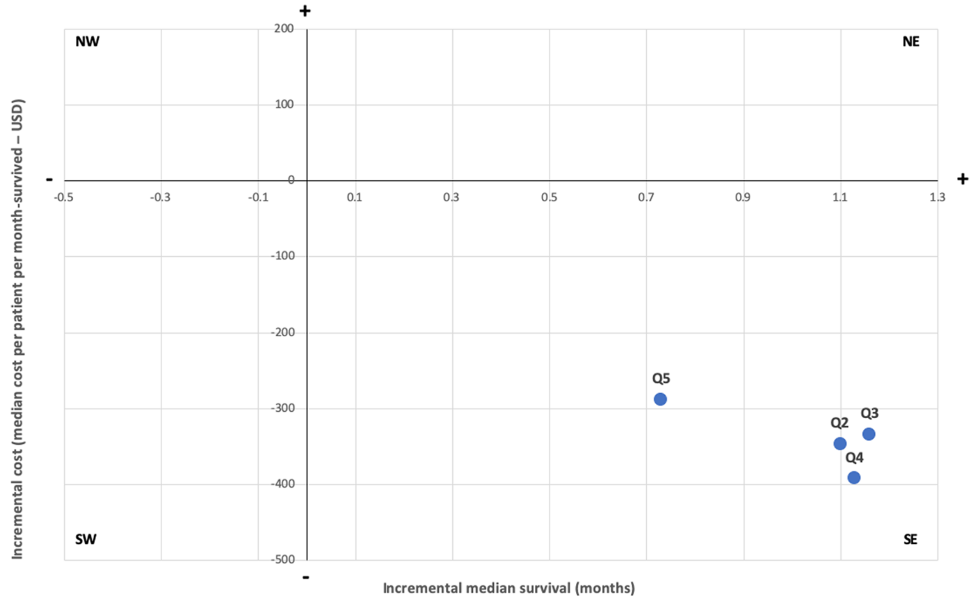

Fig. 3 Incremental costs and survival benefit in a sensitivity analysis varying the cut-off to define high-volume providers. *NE* northeast, intervention is cost-effective, *SE* southeast, intervention is cost-dominant, *SW* southwest, intervention is cost-effective, *NW* northwest, intervention is cost-dominated

Provider-volume quintile	Q2	Q3	Q4	Q5
Number of patients per provider per year	6	8	11	15
Number of patients treated by high-volume providers (%)	5,016 (71.5%)	3,735 (53.3%)	2,518 (35.9%)	1,302 (18.6%)

survival, or by delivering integrated multi-disciplinary care that can prevent the need for hospitalization. In addition, less time in acute care settings is desirable from a patient perspective.

Managing rising costs is a constant preoccupation in current healthcare systems, whether through the allocation of governmental funds in public systems, or patterns of reimbursements and business models in private systems. In this study, we provide evidence that care by high-volume providers for non-curative EGC is a dominant strategy improving both healthcare expenses and survival. Such information is important for health systems and reimbursement bodies [8, 48]. The dominant observation from this study could be explained by reduced unwarranted variation and inefficiencies in care delivery with high-volume providers resulting in scale economies and cost containment through better use of resources yielding longer survival [9, 49-51]. This should be taken into consideration when building policies and care pathways for effective, efficient, and quality cancer care.

There are some study limitations. Due to the retrospective and administrative nature of the work, the data used were not collected specifically to answer the research question. In particular, we lacked some information regarding disease characteristics, such as stage and tumor burden, and clinical trials data. The definition of high volume relied on quintiles, but other strategies have been used to define high volume [2]. The exact number defined herein may not perform the same in other jurisdictions. While the absolute cutoff may differ depending on the health system and practice setting, the observations regarding a high-volume practice concept remain valid. Finally, this study was conducted within the Canadian universally accessible and funded healthcare system, which can impact generalizability to other systems. However, prior work has shown that the attitudes of medical oncologists regarding the delivery of systemic therapy does not differ between the USA and Canada, despite differences in accessing and funding drugs [52]. Furthermore, the literature on surgical volume-outcome has yielded similar conclusions in various health systems across Canada, the USA, and Europe, supporting the generalizability of such findings [53-56]. Referral bias should be expected between low and high-volume providers, whereby more motivated patients may seek high-volume providers, or be referred from a low-volume to a high-volume provider, which we have accounted for as best as possible with multivariable modeling. Another issue is the variable length of follow-up in the cohort and between groups, with patients cared for by low-volume providers having shorter survival. We addressed this by reporting costs per patient per month-lived and conducting sensitivity analyses varying the time horizon to acquire costs.

This study offers a comprehensive analysis of healthcare costs with complete, reliable, and robust data available across the care continuum, within a universal healthcare system where insurance status does not confound access to and receipt of care. We were able to use real-life data for both costs and associated survival to directly relate costs to clinical benefits.

Conclusion

Care by high-volume providers for non-curative EGC is associated with superior survival and lower healthcare costs, indicating a dominant strategy, compared to care by low-volume providers. Lower inpatient acute care costs for high-volume providers was the main driver of the cost difference, despite higher costs for chemotherapy and radiotherapy provided by high-volume providers. Facilitating care by high-volume providers could provide an opportunity to improve outcomes for patients, while being cost-effective from a health systems perspective.

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Author contribution Concept and study design: JH, NGC. Data acquisition and analysis: JH, NJLH, VZ, LED, VG, CCE, NM, NGC. Data interpretation: JH, NJLH, VZ, LED, VG, CCE, NM, NGC. Manuscript draft and critical revision: JH, NJLH, VZ, LED, VG, CCE, NM, NGC.

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Compliance with ethical standards

Conflict of interest JH has received speaking honoraria from Ipsen Biopharmaceuticals Canada and Novartis Oncology. NGC received salary support from Cancer Care Ontario as the Clinical Lead for Patient-Reported Outcomes and Symptom Management.

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