

Rates and predictors of consideration for adjuvant radiotherapy among high-risk breast cancer patients: a cohort study

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Abstract Radiotherapy (RT) after breast conserving surgery (BCS) represents the standard for local control of breast cancer (BC). However, variations in practice persist. We aimed to characterize the rate of RT consideration (or referral) after BCS and identify predictors in Quebec, Canada, where universal health insurance is in place. A historical prospective cohort study using the provincial hospital discharge and medical services databases was conducted. All women with incident, non-metastatic BC (stages I–III) undergoing BCS (1998–2005) were identified. Odds ratios (ORs) and 95 % confidence intervals (CIs) for RT consideration were estimated with a generalized estimating equations regression model, adjusting for clustering of patients within physicians. Of the 27,483 women selected, 90 % were considered for RT and 84 % subsequently received it. Relative to women 50–69 years old, younger and older women were less likely to be considered: ORs of 0.82 (95 % CI 0.73–0.93) and 0.10 (0.09–0.12), respectively. Emergency room visits and hospitalizations unrelated to BC were associated with

decreased odds of RT consideration: 0.85 (0.76–0.94) and 0.83 (0.71–0.97). Women with regional BC considered for chemotherapy were more likely to be considered for RT: 3.41 (2.83–4.11). RT consideration odds increased by 7 % (OR of 1.07, 95 % CI 1.03–1.10) for every ten additional BCSs performed by the surgeon in the prior year. Social isolation, comorbidities, and greater distance to a referral center lowered the odds. Demographic and clinical patient-related risk factors, health service use, gaps in other aspects of BC management, and surgeon's experience predicted RT consideration.

Keywords Guidelines · Radiotherapy · Breast cancer · Consideration

Abbreviations

RT	Radiotherapy
BC	Breast cancer
BCS	Breast conserving surgery
CRID	Designated referral center

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OR	Odds ratio
CI	Confidence interval
NCCN	National comprehensive cancer network
RAMQ	Régie de l'assurance maladie du Québec
SSI	Social isolation index
MSSS	Ministère de la Santé et des Services sociaux
MED-ÉCHO	Maintenance et exploitation des données pour l'étude de la clientèle hospitalière
IRB	Institutional review board
CCI	Charlson comorbidity Index
ER	Emergency room visit
ICD	International classification of diseases
DCTD	Diffused connective tissue disease
COPD	Chronic obstructive pulmonary disease
GEE	Generalized estimating equation
CCSRI	Canadian Cancer Society Research Institute (CCSRI)
CIHR	Canadian Institutes of Health Research
FRSQ	Fonds de la recherche en Santé du Québec

Introduction

Variations in quality of care have been documented in every aspect of breast cancer (BC) management, from prevention to follow-up [8, 25, 30]. It is estimated that up to 70 % of BC patients may not be receiving the proper care for at least one component of their BC treatment [27]. In addition to affecting quality of life and health care costs, these discrepancies have been proven to result in higher recurrence rates and shorter survival [20, 37, 46]. Deviations from best practices in BC management are not limited to complex cases or difficult treatment schemas; they most often concern basic, well-established evidence-based standards of care [38].

Patients with high-risk non-metastatic BC who receive radiotherapy (RT) after breast conserving surgery (BCS) achieve significantly better local control [9, 12, 16]. The addition of RT decreases the 5-year BC local recurrence rate from 26 to 7 % [9], with a benefit that persists at 20 years of follow-up [16, 45]. In fact, the combination of BCS and RT has been shown to provide cancer control equivalent to mastectomy [15] and has therefore become the standard method of treatment as it avoids the physiological and psychological impact associated with mastectomy. Consequently, BCS followed by RT has become the standard of care according to guidelines for the management of patients with high-risk non-metastatic BC [32].

Despite this evidence, some high-risk BC patients fail to receive RT after BCS due to a variety of patient, physician, and other factors [9]. A better understanding of the risk

factors leading to suboptimal local BC control is needed to address this gap in cancer care quality. The universal health insurance program in the province of Quebec (Canada) provides a unique opportunity to study barriers to optimal health care, confounded to a lesser degree by socio-economic status [14]. To receive RT in Quebec, a patient must be seen by a radiation oncologist working at a designated referral center (CRID) [18]. Failure to receive a referral to a radiation oncologist may reflect lack of patient consideration for RT by the treating physician and thus lack of RT receipt. The primary objectives of the present study were to characterize the rate of guideline-appropriate consideration for RT in women with BC (stages I–III), who underwent BCS between Jan 1, 1998 and Dec 31, 2005 in Quebec and to identify patient- and physician-related factors that predict it.

Population and methods

Setting and data sources

The source population for this study consisted of Quebec residents, covered by the provincial health insurance plan (RAMQ) (>98 % of the province's population of >7.8 million). Data for this study was available from 1997 to 2007 and was acquired through anonymous linkage of the following databases: (1) RAMQ's registrants' database, which provides demographic and socioeconomic data including the social isolation index (SSI) [35] for registrants; (2) RAMQ's medical services database, which contains physician fee-for-service claims; and (3) Quebec's hospital abstract discharge database (MED-ÉCHO), which captures data on hospital admissions and discharge diagnoses. MED-ÉCHO is the data source for the Quebec Tumor Registry, which was used to verify that all BC were new incident cases. Appropriate ethical clearances were obtained from the Institutional Review Board (IRB) at McGill University and the Provincial Access to Information Office.

Design and study population

A historical prospective cohort study design was used. Women ≥ 18 years of age, which were diagnosed with localized or regional BC in Quebec between Jan 1, 1998 and Dec 31 and underwent BCS within 6 months of diagnosis, were identified from MED-ÉCHO. To identify these women, RAMQ procedure codes (Table 3) corresponding to BCS and primary diagnostic codes [International Classification of Diseases, 9th edition, adapted for Quebec (ICD-9-QC)] corresponding to a diagnosis for localized or regional BC [28] (Table 4) were used. Women entered the cohort in 1998 in order to ensure at least 1 year

of medical service history prior to the BCS was available for the selected patients. Women with in situ or metastatic BC, those who received a mastectomy, passed away, or became ineligible for medical insurance in the year after diagnosis, were excluded from the study population. Patients from insular or remote northern territories were also excluded (Iles-de-la-Madeleine, Nord-du-Quebec & Anticosti) on the premise that health care provision in these regions differed too much from other parts of the province, making them outliers.

Assessment of patient and surgeon characteristics

Patient and surgeon characteristics were assessed for the year prior to the patient's BCS. Age at diagnosis was calculated using the patient's date of birth, provided by the registrants' database. The residence of each patient was classified as rural or urban if the second digit of her postal code was 0 or not, in accordance with Canada Post Corporation delivery service [41]. The driving distance between the centroid of each patient's forward sortation area (first 3 characters of the postal code) and the nearest designated center of excellence for breast care in Quebec [18] was calculated in kilometers (km) using Google Maps. The comorbidity profile of each patient was assessed using the Charlson comorbidity index (CCI), calculated using the Enhanced ICD-9 coding algorithm [36] using the medical services database. The ICD-9 codes for BC were removed from the algorithm index since as all women in the cohort have BC by default. Visits to the emergency room (ER) were determined using RAMQ establishment code "0X7," corresponding to "emergency department" in the medical services database. The number and type (over-night or day cases) of hospitalizations according to surgery was determined from the MED-ÉCHO database. Conditions contraindicative for RT such as diffused connective tissue disease (DCTD), chronic obstructive pulmonary disease (COPD), or pregnancy were assessed from the medical services database using selected ICD-9 codes or RAMQ procedure codes relating to this condition (Tables 3, 4). Chemotherapy consultation and receipt were identified through the presence of claims with RAMQ procedure codes corresponding to either consultation for chemotherapy or treatment in the medical services database up to 4 months after BCS (Table 3). The stage of BC was determined using topography and morphology codes in the hospital discharge database as previously published [28].

Surgeon and hospital characteristics included number of BCSs performed prior to the selected woman's surgery. RAMQ procedure codes were used to determine the number and type of BC surgeries from the medical services database (Table 3). Surgeons were classified as either general surgeons (RAMQ specialty code of 24) or "other" surgeons.

Assessment of outcome

RT consideration was ascertained through the presence of claims with RAMQ procedure codes corresponding to either consultation with a radiation oncologist (RAMQ physician specialty code of 30) or treatment in the medical services database up to 1 year after diagnosis, as per guideline recommendations [34] (Table 4). It was assumed that if a woman received a consultation for RT but no subsequent treatment, she had been considered for therapy.

Data analysis

A generalized estimating equation (GEE) model [26] with logit link and exchangeable working correlation structure was constructed to assess the association between predictor variables and RT consideration after taking into account the clustering of patients' characteristics treated by the same physician (i.e., physician was repeated over patients). The distribution was assumed to be binomial. Univariate analysis was performed to assess the unadjusted associations between each predictor and the outcome. Subsequently, all predictors were included in the GEE model. Collinearity between variables was assessed via a Pearson correlation matrix and, as a result, residence was left out of the model due to its correlation (coefficient of ≥ 0.5) with distance to hospital. In addition, interaction terms "considered for chemotherapy" and "cancer stage" were tested based on the premise that having been considered for chemotherapy and patient's BC stage may have influenced RT consideration but were found not to be significant. Subsequently, stepwise selection of significant variables was performed. The working correlation of the final GEE model was 0.030. All *P* values are for two-tailed tests with statistical significance defined as $P \leq 0.05$. SAS software (SAS version 9.2, SAS Institute, Inc., Cary, NC) was used for all analyses.

Results

Patient characteristics

In total, 42,800 women were diagnosed with incident BC in Quebec between Jan 1, 1998 and Dec 31, 2005. Of these, 15,317 (35.8 %) were excluded because they had in situ ($N = 4,549$) or metastatic BC diagnosis ($N = 215$), died ($N = 2,443$) or became ineligible for medical insurance within 1 year of diagnosis ($N = 53$), were treated with mastectomy ($N = 5,922$) or did not have a breast surgery at all ($N = 2,075$), or lived in remote outlier regions ($N = 60$). The remaining 27,483 women comprised the

Table 1 Baseline demographic and clinical characteristics of patients ($N = 27,483$)

Patient characteristics	Value
Age (years) [n (%)]	
<50	6,189 (22.6)
50–69	14,958 (54.5)
70–79	4,622 (16.8)
≥80	1,714 (6.2)
Mean (SD)	59.5 (12.5)
Range	18–99
Year of BCS [n (%)]	
≤2000	6,893 (25.1)
>2001	20,576 (74.9)
Stage of tumor [n (%)]	
Localized	19,901 (72.4)
Regional	7,582 (27.6)
SII [n (%)]	
Less isolated (values 1–3)	15,242 (55.5)
More isolated (values 4–5)	11,345 (41.3)
N/A ^a	896 (3.3)
Residence [n (%)]	
Urban	22,772 (82.9)
Rural	4,711 (17.1)
Distance to designated radiotherapy center (km) [n (%)]	
<20	19,151 (69.7)
20–49	4,565 (16.6)
50–99	1,849 (6.7)
≥100	1,918 (7.0)
Mean (SD)	30.7 (59.8)
Range	0.5–352.0
CCI ^b [n (%)]	
0	21,026 (76.5)
1	4,441 (16.2)
2	1,426 (5.2)
3+	590 (2.1)
ER visits unrelated to BC ^c [n (%)]	
Yes	20,615 (75.0)
No	4,376 (15.9)
Overnight hospitalizations unrelated to BC ^c [n (%)]	
Yes	1,509 (5.5)
No	25,974 (94.5)
Contraindicated for RT conditions ^c [n (%)]	
Diffuse diseases of connective tissue	71 (0.3)
Chronic pulmonary disease	2,713 (9.9)
Pregnancy	35 (0.1)
RT status ^d [n (%)]	
Had consult and started	23,205 (84.4)
Had consult but did not start	1,559 (5.7)
Had no consult	2,719 (9.9)
Chemotherapy status ^e [n (%)]	
Had consult and started	6,928 (25.2)

Table 1 continued

Patient characteristics	Value
Had consult but did not start	7,016 (25.5)
No consult	13,539 (49.3)
Number of BC treating physicians ^d	
Mean (SD)	4.2 (2.3)
Range	1–21
Surgeon's speciality ^c [n (%)]	
General surgery	27,393 (99.7)
Other surgical specialties	90 (0.3)
Surgeon's case volume ^e	
Mean number of BCSs (SD)	51.3 (51.8)
Range	0–279

SD Standard deviation, BCS breast conserving surgery, SII social isolation index, N/A unavailable, CCI Charlson comorbidity index, ER emergency room, BC breast cancer, RT radiotherapy

^a SII was not available for a small subset of the population

^b ICD-9 codes for BC were removed from the coding algorithm for the CCI since as all women in the cohort had BC by default

^c Assessed in the year prior to BCS

^d Assessed in the year after BCS

^e Assessed up to 4 months after BCS

study population. All of these women were diagnosed with non-metastatic BC (stages I–III) and treated with BCS within 6 months of diagnosis. Mean age was 60 years (range: 18–99), 72 % of women had localized BC, 77 % did not have major comorbidities (CCI of 0) (Table 1). Demographically, 83 % of women lived in urban areas, 70 % of women lived within 20 km from a designated referral center, and 56 % of women were not considered socially isolated (SSI ≤ 3). Less than 1 % of the cohort had DCTD or pregnancy during treatment, while 10 % had COPD. About 6 and 75 % of women had an over-night hospital admission or an ER visit, respectively, both unrelated to their BC in the year prior to BCS.

Physician characteristics

On average, women saw 4 physicians (range: 1–21) for their BC in the year after their BCS. Of the surgeons who performed this cohort's BCSs, 99 % were general surgeons. The latter performed an average of 52 BCS (range: 0–279) in the prior year.

Use of RT in Quebec

Overall, 24,764 (90 %) of women with incident, non-metastatic BC having undergone BCS were considered for RT (i.e., received a consultation or referral) within a year. Of those, 84 % subsequently received RT.

Factors associated with RT consideration

Results of the statistical analysis of factors associated with consideration of postoperative RT are described in Table 2. Relative to the largest age group (50–69 years), odds ratios (ORs) for groups <50, 70–79, and ≥ 80 years were 0.82 [confidence interval (CI) 0.73, 0.93], 0.55 (0.48, 0.61), and 0.10 (0.09, 0.12), respectively. Relative to those living close to a designated RT center, those living far had a significantly less likely to be considered for RT, OR 0.96 (0.94–0.97) per 20 km increase in distance. Less socially isolated women (SII of 1–3) were more likely to be considered for RT, OR 1.16 (1.06–1.26) compared to more socially isolated ones (SII of 4–5). Relative to women with CCI of 0, those with CCI of ≥ 3 (moderate to severe comorbidities) were less likely to be considered for RT, OR 0.79 (0.62–1.00). Women with overnight hospitalizations or ER visits, both unrelated to BC in the past year, were also less likely to be considered for RT, compared to those without, OR 0.83 (0.71–0.98) and 0.85 (0.76–0.94), respectively. Women with localized and regional BC that were considered for chemotherapy were also more likely to be considered for RT: ORs 2.27 (1.96–2.64) and 3.41 (2.83–4.11), respectively. Surgeon's volume of BCS in the previous year significantly predicted RT consideration. A 7 % increase in the odds of being considered for RT was seen for every ten additional BCS performed in the previous year by the treating surgeon: OR 1.07 (1.03–1.10).

Discussion

In this large population-based study of Quebec women with incident, non-metastatic BC (stages I–III), we found that 1 in 10 women undergoing BCS were not considered for RT. Lack of consideration for RT was associated with age extremes (younger and elderly patients being significantly less likely to be considered), social isolation, CCI, distance from a designated RT center, and certain health service use indicators such as ER visits or hospitalizations in the year before BCS. We also found that gaps in other aspects of BC care, such as lack of consideration for chemotherapy (in patients with stage III disease) or surgeon's volume of BCS were also strongly associated with lack of RT consideration.

A substantial variation in the use of RT after BCS has been reported by existing studies, ranging 57–95 % based on geographical region and study population [7, 11, 23, 44]. However, many of these studies have mostly explored the rate of RT receipt as opposed to rate of RT consideration, omitted physician-related factors [44], have been limited to patients with early-stage BC [11, 47], carcinoma in situ [1, 13], smaller sample sizes [7, 23, 33, 44], included

only older patients [39, 40]. The rate of RT receipt observed in this study (84 %) is similar to studies using insured populations. However, less is known about the impact of treatment decisions by the physician on access to RT, especially for young or middle-aged women with locally advanced BC. We found only three studies [3, 33, 44] that evaluated the rate of RT consideration. They reported values in range of 77–94 %, which were consistent with our study.

Older age [2, 11], distance to RT centers [31], rural, isolated, ethnic, or unmarried status [3], and the presence of comorbidities [2] have been consistently reported as a risk factors for RT non-receipt across the literature. However, the link between RT non-consideration and these demographic and clinical factors remains poorly understood. It may reflect a certain level of physician non-compliance with practice guidelines in addition to patients' treatment preferences or patients' barriers to access of health care such as distance, age, or socioeconomic status. We observed that women less than 50 years were less likely to be considered for RT compared to the 50–69 age group, which is concerning since these women have a greater chance of recurrence, longer life-expectancy, and have been shown to be less persistent and adherent to future therapy such as adjuvant hormonal therapy [21]. Younger women with cancer have unique medical, psychosocial, and economic challenges that might be decreasing their odds of consideration for treatments such as RT by some physicians [5]. Further research is required to understand the challenges unique to this population.

Our study found that healthcare service utilization indicators such as overnight hospitalizations and ER visits, both unrelated to BC, in the year before BCS, were associated with a lower chance of being considered for RT after BCS after adjustment for comorbidities. Such indicators might be reflective of additional comorbidities and/or lack of affiliation with a family physician resulting in a lack of continuity and comprehensiveness of care [29]. In addition, a tendency to underestimate comorbidity in claims data has been previously shown [10] and this may have lowered the explanatory power of the CCI index in this study. This may explain why women with such health service utilization indicators were in a worse position for being considered for RT, compared to women without such indicators. Efforts to increase continuity of care may improve treatment outcomes in BC care.

Variations in quality of care have been documented in other aspects of cancer care from prevention to management and follow-up and stem from complex interplay of patient, provider, and institutional factors [8, 25, 30]. In this study, we observed that women with stage III disease that were considered for chemotherapy had stronger odds for RT consideration compared to those not considered for

Table 2 Patient-related demographic and clinical predictors of radiotherapy consideration

Predictors	% considered for RT ^a		No. of patients	Univariate analysis ^b			Multivariate GEE analysis ^c		
				OR	95 % CI	P	OR	95 % CI	P
Age (years)									
<50	93.3		6,189	0.97	0.86–1.09	0.600	0.82	0.73–0.93	0.002
50–69	93.6		14,958	1.00	Referent		1.00	Referent	
70–79	87.9		4,622	0.45	0.41–0.50	<0.001	0.55	0.48–0.61	<0.001
≥80	53.9		1,714	0.07	0.07–0.08	<0.001	0.10	0.09–0.12	<0.001
Social isolation index									
Less isolated (values 1–3)	91.2		15,242	1.28	1.18–1.39	<0.001	1.16	1.06–1.26	<0.001
More isolated (values 4–5)	89.1		11,345	1.00	Referent	0.006	1.00	Referent	
N/A	84.2		896	0.65	0.54–0.79	<0.001	0.74	0.61–0.89	0.001
Charlson comorbidity index									
0 (none)	91.2		20,615	1.00	Referent		1.00	Referent	
1	88.0		4,376	0.71	0.64–0.78	<0.001	0.93	0.84–1.04	0.191
2	86.5		1,430	0.66	0.56–0.77	<0.001	0.86	0.71–1.04	0.123
≥3 (moderate or severe)	83.0		1,062	0.46	0.37–0.57	<0.001	0.79	0.62–1.00	0.046
Hospitalizations, unrelated to BC, in year before BCS									
Over-night hospitalization(s)	83.0		1,509	0.51	0.44–0.59	<0.001	0.83	0.71–0.98	0.024
No over-night hospitalizations	90.5		25,974	1.00	Referent		1.00	Referent	
ER visits, unrelated to BC, in year before BCS									
Yes	86.9		6,868	0.65	0.59–0.70	<0.001	0.85	0.76–0.94	0.002
No	91.2		20,615	1.00	Referent		1.00	Referent	
Chemotherapy and tumor stage									
No consult, localized cancer	84.4		10,920	1.00	Referent		1.00	Referent	
Had consult, localized cancer	92.7		8,981	2.36	2.14–2.59	<0.001	2.27	1.96–2.64	<0.001
No consult, regional cancer	94.3		2,619	3.09	2.60–3.67	<0.001	2.22	1.84–2.67	<0.001
Had consult, regional cancer	95.7		4,963	4.12	3.56–4.77	<0.001	3.41	2.83–4.11	<0.001
Surgeon's case volume in previous year									
	Mean	SD		Univariate analysis ^b			Multivariate GEE analysis ^c		
				OR	95 % CI	P	OR	95 % CI	P
Per 10 breast surgeries increase	52.3	51.9		1.05	1.04–1.06	<0.001	1.07	1.03–1.10	<0.001
Distance to designated center for excellence in breast Care (km)									
Per 20 km increase	29.6	58.4		0.97	0.96–0.98	<0.001	0.96	0.94–0.97	<0.001

CI Confidence interval, OR odds ratio, ER emergency room, N/A missing or unavailable data, GEE generalized estimating equations, P P value

^a Included were patients who received a consultation for radiotherapy up to 1 year after diagnosis, as per guideline recommendations

^b Unadjusted associations were assessed using bivariate analysis between outcome and characteristics

^c Multivariate logistic regression using a GEE model with an exchangeable working correlation (value of 0.019) to account for clustering of patients ($N = 27,483$) within physicians ($N = 424$) was used to assess associations between predictors adjusted for pre-existing conditions, residence, year of diagnosis, stage of tumor, and surgeon's specialty. The mean cluster size was 64.7 patients, range: 1–796

chemotherapy even after adjusting for clustering of patients within the same physician. This may imply that gaps in one aspect of BC care may increase the odds for gaps in other aspects of BC care such as RT consideration resulting in worse outcomes after a diagnosis of cancer for some patients and elevated health care spending. These gaps represent factors that are potentially modifiable. Implementation of electronic medical records-based tools

[42], increasing continuity of care and telemedicine [43] can help primary care providers keep track of recommended treatments tailored to each individual patient's health status and insure proper continuum of cancer care for his or her patients in a cost-effective manner. We further demonstrated that women who lived farther away from designated RT centers were significantly less likely to be considered for RT (4 % decrease for every 20 km

increase in distance) after adjusting for other covariates. It is well known that women living further from RT centers have a lower likelihood of receiving RT [31], but an association between distance and lack of consideration suggests that distance might be a barrier not only to patients but also to physicians as well when it comes to providing a referral. During a self-administered survey of physician referral practices for hereditary breast cancer, conducted by Koil et al., rural-practice physicians reported several barriers including “distance of services,” “lack of awareness of services,” “lack of effective risk reduction or clinical management,” and “patients not interested” ($P < 0.05$) [24]. Telemedicine could aid in providing referrals for RT to eligible patients, who currently do not get considered due to distance barriers.

Similar to other studies [22], we found that surgeons with higher volume of BCSs were significantly more likely to comply with guidelines and provide a consultation for RT compared to lower volume surgeons (7 % increase for every 10 additional lumpectomies). We observed a similar relationship between high-volume centers and treatment outcomes (results not shown). Birkmeyer et al. [4] found that high-volume hospitals have better outcomes in large part because patients at these hospitals are more likely to be treated by high-volume surgeons and that standards based on surgeon volume as well as hospital volume would be more useful in directing patients to the providers who are likely to achieve the best outcomes. They hypothesized that improving surgeon’s decision-making skills could simply be achieved by “practice”—clinical judgment and technical skill that are achieved only by surgeons who perform a specific procedure with sufficient frequency [4]. Harmon et al. [19] showed that medium-volume surgeons achieved results equivalent to high-volume surgeons when they operated in high- or medium-volume hospitals. Thus, high-volume hospitals could be allowing greater access to specialized teams in all aspects of patient care and the development of clinical pathways. Continuous education programs, redistribution of cases among a smaller number of surgeons in high-volume hospitals, and performance evaluations could ensure that surgeons meet certain practice-based competency levels or stay up to date with the most recent innovations in cancer care.

This study has several limitations. Similar to other studies that use administrative claims, there was no information on provider’s reasoning or on tumor factors such as size of margins, histology grade, and the presence of comedo necrosis. The availability of prior data was not sufficient to allow us to control for patients with childhood Hodgkin Lymphoma, a contraindication for RT due to prior RT. However, given the low incidence rate of this disease in the Canadian population (3 per 100,000) [6], had we

controlled for this, at most one patient would have been excluded. The CCI might underestimate the true patient comorbidity profile because the coding algorithm flags only diagnoses arising from comorbidities severe enough to result in medical service utilization. Nevertheless, this is the best proxy for this variable. Procedures not billed for by physicians by error and procedures performed at private clinics (an exception in Quebec) were missing. The strengths of our study lie in the fact that the entire population of women undergoing BCS in Quebec was captured and that the data are robust: physicians are paid on a fee-for-service basis, and completeness and accuracy of reporting have monetary incentives attached [17].

Conclusion

We found that 1 in 10 women with high-risk, non-metastatic BC that underwent BCS in Quebec between 1998 and 2005 did not get considered for guideline-recommended RT. The younger and elderly women, socially isolated or those who lived far from designated RT centers, those with multiple comorbidities, hospital admissions, or ER visits in the past year were significantly less likely to be considered for RT. Women with stage III BC not considered for chemotherapy were also less likely to be considered for RT, suggesting that gaps in one aspect of cancer care quality may increase the odds of gaps in other aspects of treatment. Surgeon case volume in the previous year was associated with greater odds of RT consideration. Strengthening continuity of care and implementing tools such as electronic medical records and telemedicine could minimize some disparities and ensure timely delivery of care. Further investigation is required to better understand the relationship between surgeon volume and compliance with guidelines of care.

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Conflict of interest The authors have no conflict of interest to declare.

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Appendix

See Tables 3 and 4

Table 3 RAMQ Procedure codes

Variable	RAMQ procedure code	Description
BCS (i.e. lumpectomy)	01174, 01175, 01201, 01204, 01205, 01228, 01229	Partial excision of breast
Pregnancy	00910, 00911, 00921, 00923, 06900, 06902, 06903, 06905, 06906, 06908, 06909, 06912, 06913, 06919, 06923, 06924, 06938, 06939, 06941, 06943, 06945, 06946, 06947, 06948, 06949, 06950, 06951, 06952	Procedures related to the care of pregnant women
Consultation for chemotherapy	09127, 09165, 09129, 015000, 015001, 015002, 09150, 09160, 09094, 09012, 09152, 015005, 015007, 015008, 015009, 015010, 09162, 09170, 09164, 015020, 015021, 015022,	Procedures corresponding to chemotherapy visit, consultation or follow-up
Treatment with chemotherapy	0734	Chemotherapy injection
Consultation for RT	09060, 09078, 09080, 09127, 09150, 09152, 09160, 09162, 09164, 09165, 09170, 09171, 09129	Procedures corresponding to consultation between patient and radiation therapist
Treatment with RT	08520, 08519, 09131, 09133, 09134, 09141, 09143, 09144, 09146, 09172, 08507, 08508, 08509, 08511, 08553, 08564, 08518	Procedures corresponding to the provision of RT treatments

Table 4 ICD-9-QC Codes

Variable	ICD-9-QC code	Description
BC diagnosis	174	Malignant neoplasm of female breast
DCTD	695.4, 701.0, 710.0, 710.1, 710.2, 710.3, 710.4, 710.8, 710.9	Codes corresponding to conditions related to diffuse connective tissue disease
COPD	416.8, 416.9, 490.0, 490.9, 491.0, 491.1, 491.2, 491.8, 491.9, 492.0, 492.9, 493.0, 493.1, 493.9, 494.0, 494.9, 495.0, 495.1, 495.2, 495.3, 495.4, 495.5, 495.6, 495.7, 495.8, 495.9, 496.0, 496.9, 500.0, 500.9, 501.0, 501.9, 502.0, 502.9, 503.9, 504.0, 504.9, 505.0, 505.9, 506.4, 508.1, 508.8	Codes corresponding to various pulmonary conditions

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