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CLINICAL INVESTIGATION **Breast Cancer**

RADIATION THERAPY AFTER BREAST-CONSERVING SURGERY: DOES HOSPITAL SURGICAL VOLUME MATTER? A POPULATION-BASED STUDY IN TAIWAN

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Purpose: To examine the association between hospital surgical volume and the use of radiation therapy (RT) after breast-conserving surgery (BCS) in Taiwan.
Methods and Materials: We used claims data from the National Health Insurance program in Taiwan (1997–2005) in this retrospective population-based study. We identified patients with breast cancer, receipt of BCS, use of radiation, and the factors that could potentially associated with the use of RT from enrollment records, and the ICD-9 and billing codes in claims. We conducted logistic regression to examine factors associated with RT use after BCS, and performed subgroup analyses to examine whether the association differs by medical center status or hospital volumes.
Results: Among 5,094 patients with newly diagnosed invasive breast cancer who underwent BCS, the rate of RT was significantly lower in low-volume hospitals (74% vs. 82%, $p < 0.01$). Patients treated in low-volume hospitals were less likely to receive RT after BCS (odds ratio = 0.72, 95% confidence interval = 0.62–0.83). In addition, patients treated after the implementation of the voluntary pay-for-performance policy in 2001 were more likely to receive RT (odds ratio = 1.23; 95% confidence interval = 1.05–1.45). Subgroup analyses indicated that the high-volume effect was limited to hospitals accredited as non–medical centers, and that the effect of the pay-for-performance policy was most pronounced among low-volume hospitals.
Conclusions: Using population-based data from Taiwan, our study concluded that hospital surgical volume and pay-for-performance policy are positively associated with RT use after BCS. **© 2012 Elsevier Inc.**

Breast cancer, Breast-conserving surgery, Surgical volume, Radiotherapy, Pay-for-performance.

INTRODUCTION

Radiation therapy (RT) after breast-conserving surgery (BCS) is considered to be the standard of care for women with local regional invasive breast cancer who choose BCS over mastectomy (1–5). Among these patients, RT is associated with improvement in loco-regional disease recurrence and survival in studies of long-term follow-up (2, 6, 7). In a meta-analysis, RT reduced the 5-year local disease recurrence rate from 26% to 7% and improved the 15-year breast cancer mortality from 35.9% to 30.5% (7). Therefore, numerous professional societies have included RT after BCS as an important quality-of-care indicator (2, 3). Similar recommendations can also be found in the practice guidelines of local medical associations or official Web sites in Taiwan (8–10). As these recommendations for RT after BCS (including those suggested by the Bureau of National Health Insurance [BNHI]) are not mandatory, the BNHI initiated a voluntary pay-for-performance policy in 2001 for six diseases, including breast cancer (8). Although there is no established guideline for this policy, participating hospitals were encouraged to follow the NCCN guideline (3).

In Western countries, BCS has been widely accepted as a viable alternative to mastectomy in the treatment of

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loco-regional breast cancer since the publication of findings from several large-scale randomized trials initiated in the 1970s (6). Studies documenting breast cancer treatment patterns in the United States or Europe have reported a trend toward an increasing use of BCS (11–13). Despite a cautious, slower uptake of BCS recommendations in the Far East in the recent past, several studies have reported a growing trend of BCS in Singapore, Japan, Malaysia, Taiwan, and Hong Kong since the 1990s (14–18). More recently, evidence regarding the benefit of BCS among breast cancer patients in Asia has become available. These studies confirmed the efficacy of BCS as compared to mastectomy (19, 20) and documented the improvement in quality of life as well as patient satisfaction with the cosmetic results (21–23). In addition, studies have established the clinical benefit of RT after BCS among Asian women with loco-regional breast cancer (24, 25).

Numerous studies have examined the use pattern of RT after BCS and explored the associated factors (5, 11–13, 25–40). These studies of Asian cohorts of breast cancer patients were based on survey data, clinical trial data, or databases from a single institution or a cluster of institutions (25, 27, 30, 34, 39). To date, there are no published population-based studies reporting the use pattern of RT among breast cancer patients who underwent BCS in the Far East.

The relationship between surgical outcomes of patients with breast cancer and high-volume providers of such procedures has been examined in the literature (41, 42). However, the literature provides very little evidence to determine whether the volume-outcome relationship goes beyond surgical outcomes and extends to other quality indicators in the continuum of care for breast cancer patients. To our knowledge, only one study has explored this issue (38). Using claims data from the National Health Insurance program in Taiwan, we conducted a population-based study to address that same question. In addition, we explored whether a reimbursement policy, such as pay-for-performance, offers an effective mechanism to reduce the difference in quality of care between high- and low-volume hospitals.

METHODS AND MATERIALS

Institutional background and data source

The primary datasets used in our study were extracted from the National Health Insurance Research Database (NHIRD) in Taiwan. The NHI program, established in 1995, is a single-payer, compulsory social insurance program that provides insurance coverage to every citizen in Taiwan. Services covered under the NHI include outpatient visits, hospitalization, home nursing care, certain screening and preventive services, laboratory tests and diagnostic imaging, and dental care (43, 44). As of 2007, 22.6 million persons among Taiwan's population of 22.96 million were enrolled in this program. Like most health insurance programs worldwide, the NHI program in Taiwan contains a cost-sharing scheme. Beneficiaries under the NHI are required to pay a monthly premium to keep their enrollment active, as well as co-payments for medical care services they use. The NHI also includes a catastrophic illness program to protect population subgroups that may become financially vulnerable because of illnesses. Since the end of 2001, 30 medical conditions, including cancer, have been classified as "major illness conditions," and individuals with any of those conditions are exempt from co-payments for all medical services deemed relevant to those conditions.

The National Health Research Institutes (NHRI) maintains a data warehouse to store the enrollment file and original claims data for all services reimbursed by the NHI. To facilitate researchers using these data, the NHRI created the NHIRD with scrambled person and medical facility identifiers that allows for linkage between enrollment records, claims, and providers, and makes the database accessible to researchers in Taiwan through a process of data acquisition and approval (45). As of December 31, 2009, the NHI Research Database had been used in more than 200 studies (45).

For this study, we used the following files from the 1997–2005 NHIRD database: catastrophic illness registry, ambulatory care expenditures (CD), details of ambulatory care orders (OO), details of inpatient orders (DO) and inpatient expenditures (DD). The CD and OO files provide up to three ICD-9 diagnosis codes and one ICD-9 procedure code for each outpatient encounter. The files also contain billing records for claims reimbursed by the NHI, including claims for radiation therapy. The DD and DO files provide up to five ICD-9 diagnosis codes and five procedure codes, as well as billing records for each hospital admission. In addition, using unique facility identifiers, we are able to link claims to medical facility files to obtain facility characteristics, such as geographic location and ownership type.

This study was exempt from the Institutional Review Board at the University of Texas M. D. Anderson Cancer Center because the NHIRD database contains deidentified person identifiers.

Study design and selection of study population

We conducted a retrospective population-based study to examine the relationship of receiving BCS at a high-volume facility and the subsequent use of RT among female patients with breast cancer, while controlling for other plausible confounders of the receipt of RT. We identified the study population using the ICD-9 code for female invasive breast cancer (174.xx) from the Catastrophic Illness Registry file. We then identified BCS from claims and limited the sample to those with BCS and no record of mastectomy. A detailed algorithm of our inclusion/exclusion criteria is depicted in Fig. 1.

Study variables

We defined the date of BCS as the index date and identified RT as the receipt of teletherapy or brachytherapy within 12 months of the BCS (Fig. 1). In the previous breast cancer volume-outcome studies, a high-volume status was generally defined by either an absolute number. e.g., 50 cases per year (38), or the relative volume among hospitals, e.g., by quartiles (46). We chose to use the relative volume of BCS for the present study because this surgical procedure is becoming increasingly prevalent in Taiwan, which makes it less meaningful to use an absolute number as the threshold to define high-volume hospitals. We calculated the surgical volume for each hospital as the number of BCSs performed each year from 1998 to 2004, and categorized high-volume hospitals as those with surgical volumes at the top 10th percentile of the distribution in each year. The decision to define high-volume hospitals as those with surgical volumes in the top 10th percentile of the distribution, instead of the top quartile, was driven by an observation that a criterion based on the top quartile would result in the classification of over 93% of patients into the high-volume category, leaving little variability for the statistical analyses.

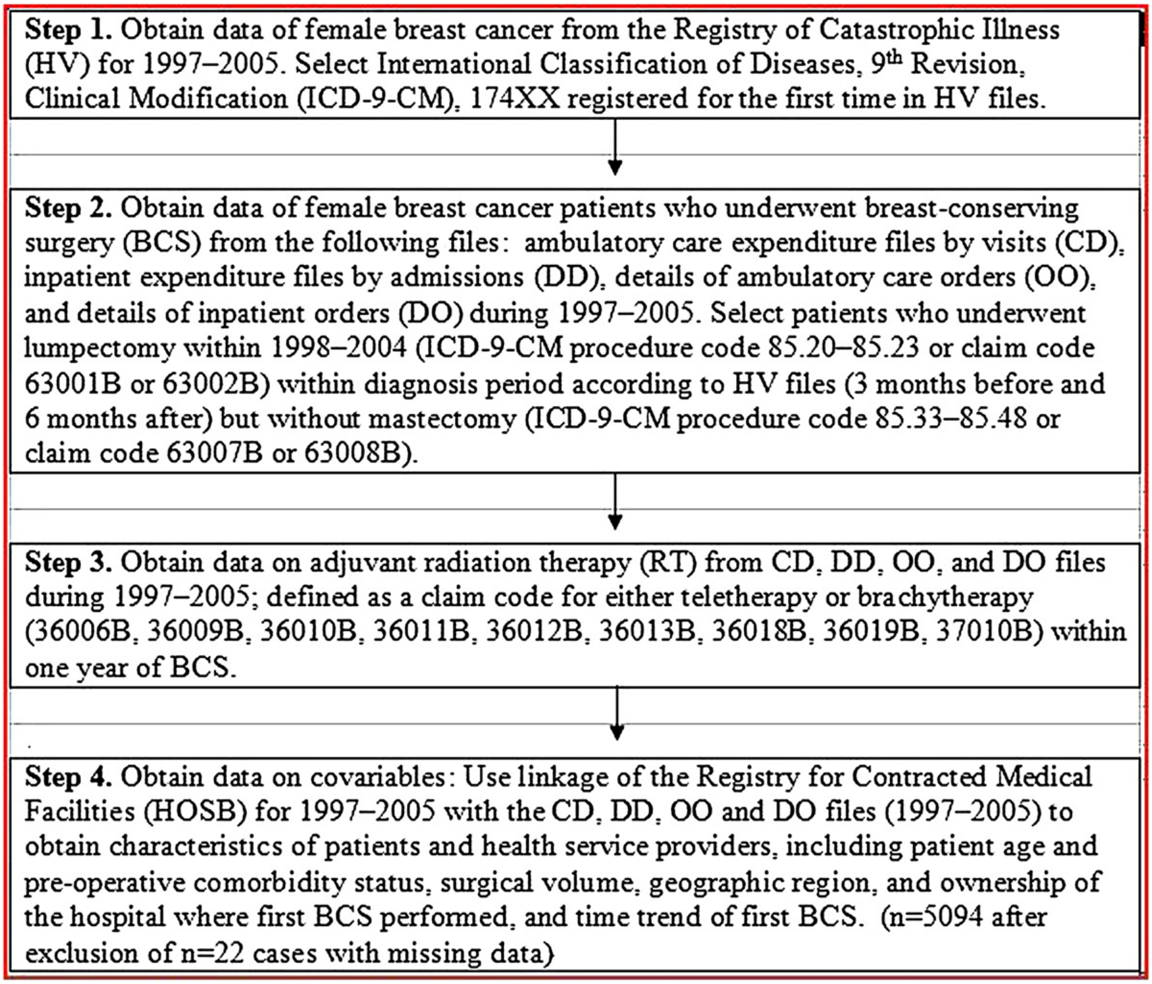

Fig. 1. Inclusion and exclusion algorithm.

Other covariates in the multivariate analyses included patient characteristics (age, comorbidity), and characteristics of the hospitals where BCS was performed (ownership and geographic region). We classified age at BCS into four categories: <40, 40–49, 50–64, and ≥65 years. We derived patients' comorbidity scores by using an algorithm initially developed by Klabunde *et al.* (47–50), but modified specifically for the NHI claims data (51). We categorized the ownership type of the hospital into public vs. nonpublic and classified the geographic characteristic of the hospitals among four regions: Taipei metropolitan, North, Middle, and South/East (including the Kaoping area) Taiwan. In addition, to capture a possible policy effect from a voluntary pay-for-performance program initiated by the NHI in 2001 to encourage guideline-compliant treatment patterns, we included a binary variable to examine whether an increasing use of RT was observed after this policy was implemented.

Statistical analysis

We conducted bivariate and multivariate analyses to investigate factors associated with RT use after BCS. In bivariate analysis, we compared patients' and providers' characteristics between women with breast cancer who received and those who did not receive RT after BCS. We used chi-squared tests to assess the statistical significance between these two groups. In multivariate analysis, we performed a logistic regression model to examine the aforementioned association.

We conducted two subgroup analyses to explore how the volume–outcome relationship interacts with a facility's medical center status and the voluntary pay-for-performance policy. In the first subgroup analysis, we performed separate logistic regressions for BCS patients treated in medical centers vs. non–medical centers because a large proportion of medical centers were also high-volume BCS hospitals. The official accreditation status of a hospital as a medical vs. non–medical center was obtained from the medical facility files in the NHIRD. The second subgroup analysis included separate logistic regressions for patients treated at low- vs. high-volume hospitals to determine whether the pay-for-performance policy affects these hospitals differently.

Statistical significance was defined as $p < 0.05$. We used SAS version 9.2 (SAS Institute, Cary, NC,) for data management and STATA/SE version 10.1 (Stata Corporation, College Station, TX) for statistical analyses.

RESULTS

Descriptive statistics and bivariate analysis

From the dataset we identified 5,094 Taiwanese women who had been newly diagnosed with breast cancer and treated with BCS between 1998 and 2004. Among those, 4,029 women (79%) received RT within 1 year of BCS. As shown in Table 1, the vast majority of our study population

Table 1. Bivariate analysis of adjuvant radiation therapy (RT) after breast-conserving surgery (BCS), 1998–2004

	Total		By RT status				
	Count	%	Without RT	%	With RT	%	*p* Value
Age group, y							
<40	1,236	24%	210	20%	1,026	25%	<0.01
40–49	2,158	42%	358	34%	1,800	45%	
50–64	1,286	25%	290	27%	996	25%	
≥65	414	8%	207	19%	207	5%	
Comorbidity score							
0	4,095	80%	814	76%	3,281	81%	<0.01
≥1	999	20%	251	24%	748	19%	
Hospital ownership							
Public	1,621	32%	390	37%	1,231	31%	<0.01
Nonpublic	3,473	68%	675	63%	2,798	69%	
Hospital geographic region*							
Taipei metropolitan	2,513	49%	556	52%	1,957	49%	<0.01
North	930	18%	121	11%	809	20%	
Middle	1,094	21%	256	24%	838	21%	
South and East	557	11%	132	12%	425	11%	
Hospital surgical volume of BCS							
Low	1,778	35%	456	43%	1,322	33%	<0.01
High	3,316	65%	609	57%	2,707	67%	
Medical center status							
Medical center	3,175	62%	669	63%	2,506	62%	0.711
Non–medical center	1,919	38%	396	37%	1,523	38%	
Year of BCS							
<2001	1,239	24%	283	27%	956	24%	0.054
≥2001	3,855	76%	782	73%	3,073	76%	

* Based on the location of the hospital where BCS was performed.

was younger than 65 years, and 80% of them had a comorbidity score of zero. More than 65% of the women received BCS in high-volume hospitals. In the bivariate analysis, factors found to be significantly different between the group with and without RT included age categories, comorbidity score, hospital ownership, geographic region, and whether the hospital was a high-volume hospital. No statistically significant difference was detected in the medical center status, or in the pre- vs. post–pay-for-performance policy period between these two groups, suggesting that the volume-outcome relationship may be modified by these two factors.

Multivariate analysis of the full study sample

Results from the logistic regression (Table 2) show that patients who underwent BCS in the low-volume hospitals were significantly less likely to receive RT after surgery (adjusted odds ratio [OR] = 0.72, 95% confidence interval [CI] = 0.62–0.83). We also found that patients younger than 65 years and those who resided in northern Taiwan but not in the Taipei metropolitan area were significantly more likely to receive RT after BCS, whereas those treated in public hospitals were less likely to receive RT than those in non–public hospitals. In addition, a significantly higher odds ratio was reported for patients whose BCS took place after the implementation of the voluntary pay-for-performance policy (OR = 1.23; 95% CI = 1.05–1.45).

Subgroup analyses

When we stratified patients by the medical center status of the hospitals that provided BCS (Table 3), we found that the pattern among patients treated in non–medical centers was similar to that in the full study sample except that hospital ownership was no longer significant. We observed a somewhat different pattern among patients treated in medical

Table 2. Logistic regression of factors associated with radiation therapy after breast-conserving surgery (BCS), 1998–2004

Characteristic	Adjusted OR*	95% CI
Age group		
<40	4.37	(3.40–5.61)
40–49	4.42	(3.51–5.55)
50–64	3.09	(2.44–3.90)
≥65	1.00	Referent
Comorbidity score		
≥1 vs. 0	1.04	(0.87–1.24)
Hospital ownership†		
Public vs. nonpublic	0.83	(0.71–0.97)
Hospital geographic region†		
Taipei metropolitan	0.99	(0.79–1.24)
North	1.63	(1.22–2.19)
Middle	0.91	(0.70–1.17)
South and East	1.00	Referent
Hospital surgical volume†		
Low vs. high	0.72	(0.62–0.83)
Year of BCS		
≥2001 vs. <2001	1.23	(1.05–1.45)

Abbreviations: CI = confidence interval; OR = odds ratio.
* Adjusted for all covariates included in the table.
† Where patients received BCS.

Table 3. Logistic regression of factors associated with radiation therapy after breast-conserving surgery (BCS): Subgroup analyses, 1998–2004

	By medical center status				By hospital volume			
	Medical centers		Non–Medical Centers		High-volume		Low-Volume	
	Adjusted OR*	95% CI	Adjusted OR*	95% CI	Adjusted OR*	95% CI	Adjusted OR	95% CI
Age group, y								
<40	5.89	(4.20–8.27)	3.27	(2.22–4.82)	5.51	(3.90–7.78)	3.43	(2.38–4.96)
40–49	4.92	(3.63–6.67)	4.45	(3.07–6.43)	5.20	(3.82–7.08)	3.89	(2.75–5.49)
50–64	3.60	(2.64–4.91)	2.74	(1.88–3.98)	3.90	(2.85–5.34)	2.37	(1.66–3.40)
≥65	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
Comorbidity score								
≥1 vs. 0	1.14	(0.91–1.44)	0.94	(0.69–1.26)	1.22	(0.96–1.55)	0.85	(0.64–1.12)
Hospital ownership†								
Public vs. nonpublic	1.25	(1.00–1.57)	0.85	(0.62–1.15)	0.52	(0.41–0.65)	1.01	(0.79–1.29)
Hospital geographic region†								
Taipei metropolitan	0.59	(0.44–0.80)	1.62	(1.12–2.34)	0.48	(0.33–0.69)	1.51	(1.11–2.05)
North	1.77	(1.18–2.66)	2.78	(1.68–4.61)	0.59	(0.37–0.93)	2.65	(1.66–4.23)
Middle	0.93	(0.66–1.32)	1.33	(0.86–2.05)	0.34	(0.22–0.51)	1.56	(1.09–2.23)
South and East	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
Hospital surgical volume†								
Low vs. high	1.04	(0.81–1.33)	0.36	(0.26–0.50)	N/A	N/A	N/A	N/A
Year of BCS: Before vs. after phase-in of voluntary pay-for-performance policy								
≥2001 vs. <2001	1.11	(0.90–1.36)	1.62	(1.24–2.11)	1.09	(0.87–1.36)	1.38	(1.08–1.77)

Abbreviations: CI = confidence interval; N/A = not applicable; OR = odds ratio.
* Adjusted for all covariates included in the table.
† Where patients received BCS.

centers, in that hospital surgical volume and year of BCS were no longer significant (adjusted OR with 95% CI: 1.04 [0.81–1.33] and 1.11 [0.9–1.36], respectively). The second subgroup analysis stratified patients as those treated by high- or low-volume hospitals. The most noticeable pattern was that the year of BCS (pre- vs. post-2001) was not significant for the high-volume group (adjusted OR with 95% CI: 1.09 [0.87–1.36]), but was highly significant for the low-volume group (1.38; 1.08–1.77).

DISCUSSION

Radiation therapy is the standard of care after BCS for most female patients with localized breast cancer (6). As BCS gradually becomes a well-accepted treatment alternative to mastectomy in Taiwan as well as in other Asian countries, it becomes important to examine whether the pattern of adjunct treatment after the completion of BCS adheres to clinical guidelines. The factors associated with nonadherence to these guidelines are also important. In this population-based study using claims data from the National Health Insurance program in Taiwan, we found that among the women with newly diagnosed breast cancer who underwent BCS in the period between 1998 and 2004, close to 80% received RT. We agree that it is not realistic to expect an adherence rate as high as 100%, in particular because RT may not be recommended for certain patient subgroups, such as those ≥70 years and/or with high levels of comorbidity (3). However, considering that the average age of breast cancer patients in Taiwan is younger than that of breast cancer patients in the United States, the use rate reported from our analysis suggests that efforts should be made to further improve the quality of care among female patients with breast cancer in Taiwan.

We identified several factors associated with a lower use of RT among patients undergoing BCS: older age, receiving BCS in public hospitals, and receiving BCS in hospitals with low surgical volume of this procedure. In addition, we observed geographic variations and a positive association with the implementation of the pay-for-performance policy. Associations between adjuvant RT post-BCS and many of these same factors have been reported in the literature, including age (11–13, 26, 29), surgical volume (38), provider characteristics (26, 35), and geographic region (26, 33, 35, 38). The much lower rate of RT (50%) found in the age group ≥65 years could be driven by the smaller absolute effect of RT for the elderly, which is documented in the literature (52, 53). However, the decision to withhold RT after BCS for elderly breast cancer patients deserves further evaluation in the form of an analysis of the risk-benefit tradeoff of RT in this age group. Moreover, although previous studies have found a negative association between comorbidity and the use of RT (11, 32, 33, 36, 38), this relationship was only observed in our bivariate analysis but not in our multivariate analyses. Specifically, once we added age groups to the list of covariates, the negative association was no longer statistically significant.

Findings associated with the surgical volume variable warrant more discussion. The volume-outcome literature has suggested that breast cancer patients treated in high-volume hospitals have better 5-year survival (41, 42). It is conceivable that care received after surgery, such as the use of RT, also contributes to the better long-term outcomes found among patients in high-volume hospitals. To our knowledge, only one prior study had investigated this issue. In a population-based study of 10,000 patients in Italy who underwent BCS, Rosato *et al.* reported a higher odds ratio of RT use among patients receiving BCS in high-volume hospitals (OR = 1.31, 95% CI = 1.07–1.6) (38). We reached a similar conclusion. However, we also found that this volume effect was only significant among patients treated in non–medical centers. This is possibly because of the strict accreditation requirements currently in place for hospitals in Taiwan. Each hospital is evaluated every 3 years, and, to be accredited as a medical center, each hospital must meet many structural, procedural, and even outcome indexes (54).

The positive association between hospital volumes and health outcomes has led to the discussion of a regionalization of high-volume surgical centers (55–57). Our study suggests that changes in reimbursement policy may offer another mechanism to improve the quality of care for patients with breast cancer in Taiwan, especially for low-volume hospitals. However, this speculation needs to be verified in future studies, although better care performance had been documented in the preliminary report of this policy (58). If final assessment concludes that the voluntary pay-for-performance policy was effective in increasing the use of RT for breast cancer patients treated with BCS among facilities that participated in the pay-for-performance program, policy makers in Taiwan may consider instituting a mandatory pay-for-performance reimbursement policy as one of the strategies to increase the number of breast cancer patients receiving RT. A similar pay-for-performance policy was instituted in the United States on July 1, 2007 (32). It may be reasonable to expect an increase in the use of RT after BCS in the United States. However, it is not clear whether the differential effect of the pay-for-performance policy between high- and low-volume facilities that was observed in Taiwan will be found in other countries.

It is worth noticing that the pattern of regional variation observed in the analysis with full sample differs from that reported in subgroup analyses, with the most noticeable difference found in the odds ratio associated with the Taipei metropolitan region. Specifically, although no statistically significant difference was found in the odds of receiving RT among patients treated in Taipei vs. the South/ East region, a significantly lower odds of RT for patients in the Taipei metropolitan region was found in the subgroup of medical centers (OR = 0.59; 95% CI = 0.44–0.80) and of high-volume hospitals (OR = 0.48; 95% CI = 0.33–0.69) and a significantly higher odds ratio was found in the subgroup of non–medical centers (OR = 1.62; 95% CI = 1.12–2.34) and of low-volume hospitals (OR = 1.51; 95% CI = 1.11–2.05). The above pattern could possibly be explained by factors related to unequal geographic distribution of medical resources in Taiwan. The distribution of medical resources is heavily concentrated in the Taipei metropolitan area, while the South/East region has the lowest density (59). In addition, patients in Taiwan facing severe medical conditions such as cancer have a strong preference to seek treatment in prestigious medical centers, and the majority of those centers are located in Taipei. Therefore, it is not uncommon for those patients to travel to medical centers in Taipei for BCS. The excess demand for cancer care from these medical centers likely leads to capacity issue. In the case of RT, it is possible that the department of radiation oncology in some medical centers may not have enough personnel and machines to accommodate the RT need from all BCS patients treated in these facilities. It is also possible that some of these patients had to travel to Taipei for BCS, but did not want to be away from home for another 4 to 6 weeks for their radiation therapies and yet could not find facilities offering radiation treatment in close proximity of their homes. Both factors contribute to lower odds of RT in Taipei among patients treated in medical centers. Since a large proportion of high-volume hospitals are medical centers, the above reasoning also explains the lower odds of RT observed in Taipei region in the subgroup analysis of high-volume hospitals.

Conversely, patients treated in non–medical centers or low-volume hospitals were likely to be those who chose to receive care from local facilities due to reasons such as personal preference or financial constraint. Among these subgroups, patients in the South/East region not only faced more limited availability of medical resources in this region, they also may have to travel a long distance to reach medical facilities in their areas (59). Both factors could lead to a lower likelihood of receiving RT for patients in the South/East region and thus a highly likelihood of RT use in other regions, including Taipei. The above reasoning was based on our understanding of the health care system and patients' care-seeking behavior in Taiwan and would need to be confirmed in future studies.

Our study has a number of limitations. First, the validity of a breast cancer diagnosis and RT use ascertained from the NHI claims database may be of concern. Although the validity of this database for cancer-related diagnoses and procedures is yet to be confirmed, the accuracy of this database has been validated in other diseases (60). Second, our study design and analyses addressed association, not causality. To fully understand the impact of the pay-for-performance policy on the uptake of RT after BCS, it is recommended that future studies perform a difference-in-difference analysis by linking the facility database with the participation record of the voluntary pay-for-performance program. Third, our study is limited to information collected in the NHI claims database; thus, estimates from the multivariate analysis can potentially subject to confounding bias arisen from unmeasured/unavailable covariates or residual confounding of measured variables. For example, travel distance to a radiation-treatment facility has been found to be associated with the receipt of RT after BCS among women with breast cancer patients (61); however, this variable was not included in our analysis. Future studies should explore the use of the geographic information system method to calculate the distance between patients' residence and the nearest radiation-treatment facility; such studies will also provide insights into our earlier discussion on the plausible explanations for the differential geographic patterns found in the subgroup analyses. Finally, our study focused on the uptake of RT but did not examine whether patients had completed a full course of therapy. As a recent U.S. study has reported a small but significantly positive association between incompletion of a full course of RT and the risk of breast cancer recurrence (62), an interesting topic for future research is to investigate whether the relationship between surgical volume and the use of RT observed in our study will extend to the completion of RT. Researchers interested in this topic should include the characteristics of radiation facilities as well as surgical facilities in the analysis.

Despite these limitations, our study makes several unique contributions to the literature. First, it describes the population-based use pattern of RT after BCS for women with breast cancer in the Far East. Second, it reports a positive association between RT use and the surgical volume in hospitals that perform BCS, especially among hospitals that are not medical centers. This finding suggests that the volume-outcome relationship might go beyond surgical outcomes and extend to the improvement of quality of care in the continuum of cancer care among patients with breast cancer. Finally, our study is the first to document that reimbursement policies, such as the pay-for-performance policy, may provide an effective mechanism to boost the use rate of RT, especially among low-volume hospitals. This finding suggests that policy makers may improve the quality of cancer care through regulations and reimbursement policies that incentivize providers to adhere to treatment guidelines.

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