Published in final edited form as:
Surgery. 2014 May ; 155(5): 776–788. doi:10.1016/j.surg.2013.12.009.

For-Profit Hospital Ownership Status and Use of Brachytherapy after Breast-Conserving Surgery

Sounok Sen, MD[1], **Pamela R. Soulos, MPH**[1,2], **Jeph Herrin, PhD**[1,3,8], **Kenneth B. Roberts, MD**[1,4], **James B. Yu, MD**[1,4], **Beth-Ann Lesnikoski, MD**[5], **Joseph S. Ross, MD MHS**[2,6,7], **Harlan M. Krumholz, MD**[6,7,8,9], and **Cary P. Gross, MD**[1,2,6]

[1]Cancer Outcomes, Public Policy and Effectiveness Research (COPPER) Center, Yale Cancer Center and Yale University School of Medicine

[2]Section of General Internal Medicine, Department of Internal Medicine, Yale University School of Medicine

[3]Health Research & Educational Trust, Chicago IL

[4]Department of Therapeutic Radiology, Yale University School of Medicine

[5]JFK Medical Center, Atlantis FL

[6]Robert Wood Johnson Clinical Scholars Program

[7]Center for Outcomes Research and Evaluation, Yale-New Haven Hospital

[8]Department of Cardiovascular Medicine, Yale University School of Medicine

[9]Section of Health Policy and Administration, Department of Epidemiology and Public Health, Yale University School of Medicine

Abstract

Corresponding author: Cary P. Gross, MD, Yale University School of Medicine, Primary Care Center, 333 Cedar Street, PO Box 208025, New Haven, CT 06520, phone: 203-688-8588, fax: 203-688-4092, cary.gross@yale.edu.

Data access and responsibility: All authors had full access to all the data in the study and Dr. Gross takes responsibility for the integrity of the data and the accuracy of the data analysis.

Disclosures and Conflicts of interest: Drs. Ross and Gross are members of a scientific advisory board for FAIR Health, Inc. Drs. Ross and Gross receive support from Medtronic, Inc. to develop and implement methods of clinical trial data sharing and patient-level meta-analyses. Dr. Ross is supported by the National Institute on Aging (K08 AG032886) and by the American Federation for Aging Research through the Paul B. Beeson Career Development Award Program, from the Centers of Medicare and Medicaid Services (CMS) to develop and maintain performance measures that are used for public reporting, and from the Pew Charitable Trusts to examine regulatory issues at the U.S. Food and Drug Administration. Dr. Krumholz is supported, in part, by grant U01 HL105270-03 (Center for Cardiovascular Outcomes Research at Yale University) from the National Heart, Lung, and Blood Institute in Bethesda, Maryland. Dr. Krumholz is the recipient of a research grant from Medtronic, Inc. through Yale University and is chair of a cardiac scientific advisory board for UnitedHealth.

Author contributions: Drs. Gross, Lesnikoski, and Sen and Ms. Soulos were responsible for the conception and design of this work. Drs. Gross and Sen and Ms. Soulos drafted the manuscript. Ms. Soulos conducted the statistical analysis. Dr. Gross was responsible for acquisition of data and obtained funding. Dr. Gross provided supervision. All authors participated in the analysis and interpretation of the data and critically revised the manuscript for important intellectual content.

BACKGROUND—Little is known about the relation between surgical care for breast cancer at for-profit hospitals and subsequent use of adjuvant radiation therapy (RT). Among Medicare beneficiaries, we examined whether hospital ownership status is associated with the use of breast brachytherapy – a newer and more expensive modality – as well as overall RT.

METHODS—We conducted a retrospective study of female Medicare beneficiaries receiving breast-conserving surgery for invasive breast cancer in 2008 and 2009. We assessed the relationship between hospital ownership and receipt of brachytherapy or overall RT using hierarchical generalized linear models.

RESULTS—The sample consisted of 35,118 women, 8.0% of whom had surgery at for-profit hospitals. Among patients who received RT, those who underwent surgery at for-profit hospitals were significantly more likely to receive brachytherapy (20.2%) than patients treated at not-for-profit hospitals (15.2%; OR for for-profit vs. not-for-profit: 1.50; 95%CI: 1.23–1.84; p<0.001). Among women aged 66–79, there was no relation between hospital ownership status and overall RT use. Among women aged 80–94 years old – the group least likely to benefit from RT due to shorter life expectancy – receipt of surgery at a for-profit hospital was significantly associated with higher overall RT use (OR: 1.22; 95%CI: 1.03–1.45, p=0.03) and brachytherapy use (OR: 1.66; 95%CI: 1.18–2.34, p=0.003).

CONCLUSIONS—Surgical care at for-profit hospitals was associated with increased use of the newer and more expensive RT modality, brachytherapy. Among the oldest women, who are least likely to benefit from RT, surgical care at a for-profit hospital was associated with higher overall RT use, with this difference largely driven by the use of brachytherapy.

INTRODUCTION

Surgical intervention plays a critical role in cancer treatment, affecting decisions made in the perioperative setting and the trajectory of cancer care beyond the initial ‘curative surgery’. Post-surgical cancer care often involves the adoption of new, expensive, and sometimes unproven technologies, which has raised concerns about inappropriate care and overuse.[1–4] Many factors may affect the adoption of newer medical technologies including patient and physician preferences, reimbursement incentives, clinical evidence, and regional health system factors.[5–8] Hospitals play a major role both in providing surgical care and in the adoption of new technologies, due to their ability to invest in infrastructure, their central role in the treatment of many conditions, and their being the focus of payer efforts to enhance quality and control costs. Hence, it is important to understand how hospital factors, such as ownership status, affect the adoption of new technologies after patients undergo surgery.

The effect of hospital ownership status is particularly relevant in clinical scenarios where evidence regarding treatment benefit is less definitive, and clinical decision-making is more discretionary. In this setting, hospitals owned by for-profit entities, which must return value to investors, may be more likely to encourage the adoption of highly reimbursed interventions. While both for-profit and not-for-profit hospitals have financial incentives to emphasize revenue-generating procedures, for-profit hospitals may be more responsive to these incentives given their fiduciary interests.[9–11] For example, for-profit hospital ownership has been associated with increased use of cardiac revascularization interventions

independent of clinical outcome.[11] Similarly, receipt of care at for-profit hemodialysis centers has been associated with increased erythropoietin drug dosing in excess of recommendations from clinical guidelines.[12] However, these studies focused on the use of widely used treatment strategies that had already disseminated into clinical practice with evidence-based guidelines in place. Little is known about the effect of hospital ownership status on the adoption of new medical technologies that are reimbursed at higher rates than existing technologies.[13]

Breast brachytherapy for older women with breast cancer is an excellent example of a newer therapy with scant comparative effectiveness data and higher reimbursements compared to the standard whole breast irradiation (WBI). Breast brachytherapy involves the implantation of the radiation source into the lumpectomy cavity and condenses the treatment course to 1 week compared to 4–6 weeks for WBI. Although breast brachytherapy has diffused into clinical practice, some recent data suggest that the harms may actually outweigh the benefits.[14–20] Furthermore, brachytherapy is more highly reimbursed than the standard of care, and some authors have suggested that financial interests are driving the adoption of brachytherapy in clinical practice. [21–24] It remains unknown whether surgical care at a for-profit hospital is associated with the receipt of adjuvant brachytherapy.

It is also important to consider how the adoption of brachytherapy might affect overall use of adjuvant radiation therapy (RT). That is, after disseminating into clinical practice in either profit setting, brachytherapy may substitute for the standard of care, WBI, without any increase in the overall use of RT. Alternatively, enthusiasm for brachytherapy could expand the pool of women who are assessed to be suitable candidates for RT and instead complement the standard of care, thereby increasing overall RT use. In this context, financial incentives and increased reimbursement for brachytherapy may lead to a higher overall use of RT. This may be particularly true among older women, and especially those above age 80 years, for whom the benefit of RT diminishes and thus may be more subject to provider preferences and discretionary judgment.[25–28] It remains unknown whether surgical care at a for-profit hospital is associated with brachytherapy use as a substitute for standard RT or associated with a higher likelihood of RT use overall.

To further our understanding of the relation between hospital ownership status and cancer care, we used national Medicare data to assess the relation between for-profit hospital ownership and the adoption of brachytherapy among Medicare beneficiaries with breast cancer receiving breast-conserving surgery (BCS). We hypothesized that among women receiving adjuvant RT, those who had undergone BCS at a for-profit hospital would be more likely to receive brachytherapy. We also assessed whether women undergoing BCS at for-profit hospitals would be more likely to receive RT overall. That is, we hypothesized that the use of brachytherapy in for-profit hospitals increases the proportion of women who are receiving RT, rather than simply substituting for WBI. We also hypothesized that this relation between brachytherapy and overall RT use would be stronger among older women, the group for whom RT is more discretionary.

METHODS

Data Source and Study Sample

Using the Centers for Medicare and Medicaid Services Chronic Condition Warehouse (CCW) database, we identified a sample of female Medicare beneficiaries between ages 66–94 years who received BCS and adjuvant RT for invasive breast cancer in 2008 and 2009.[29,30] The CCW is a national database that contains 100% of fee-for-service Medicare claims for inpatient and outpatient institutional and non-institutional services for patients with certain chronic conditions. We identified beneficiaries with invasive breast cancer by the International Classification of Diseases, 9th revision (ICD-9) diagnosis code (174.x). Receipt of brachytherapy or WBI (traditional external beam or intensity modulated) was identified according to Healthcare Common Procedure Coding System (HCPCS) codes (Appendix 1). We only included women who received BCS between January 2008 and June 2009 and were enrolled in fee-for-service Medicare Parts A and B during the study period. Approximately 93% of all Medicare beneficiaries are enrolled in both Parts A and B.[31] Women were excluded from this sample if they received an ICD-9 diagnosis code for any other cancer (including ductal carcinoma in situ) in the 9 months prior through 6 months after BCS (Appendix 2). The Yale Human Investigation Committee determined that this analysis did not directly involve human subjects.

Radiation Therapy

Patients with any HCPCS codes indicative of brachytherapy treatment were considered to have received brachytherapy. Patients with at least four HCPCS codes indicative of the delivery of WBI were considered to have received WBI. In order to capture all patients for whom the decision was made to provide brachytherapy as a component of their therapy, patients with codes for both brachytherapy and WBI (less than 0.5% of the total sample) were assigned to the brachytherapy group.

Construction of Variables

Patient characteristics included age, race, year of surgery, residence in a metropolitan county based on Core Based Statistical Areas, and median household income at the zip code level. Clinical characteristics such as comorbid conditions, tumor laterality, lymph node dissection (including sentinel and axillary dissection), and receipt of chemotherapy were assessed using HCPCS and ICD-9 codes from the Medicare claims (Appendix 1). As proxies for access to care, we accounted for each of the following variables in the year prior to surgery: any hospital admission, receipt of a screening mammogram, receipt of a flu shot, or primary care physician visit. Comorbid conditions previously found to be associated with survival in non-cancer patients were assessed by searching claims in the 12 months through one month prior to BCS.[32] We included ICD-9 diagnosis codes that were on an inpatient claim or ≥2 outpatient/physician claims billed >30 days apart.

For each patient, we identified the hospital at which BCS was performed using the Medicare provider number. Hospital ownership was determined from the Medicare Hospital General Information dataset which is a self-reported measure by hospitals during enrollment with the Centers for Medicare and Medicaid Services.[33] All hospitals listed as ‘Proprietary’ under the

hospital owner variable were considered for-profit. Hospitals listed as either 'Government' or 'Voluntary Non-profit' were considered not-for-profit. Patients for whom we could not identify a BCS-performing hospital or whose hospital was not included in the Hospital General Information dataset were excluded (n=6194, 15%). Hospital volume was calculated as the number of patients in our sample who received surgery at each hospital during the study period. The sample was categorized into quintiles of volume such that each quintile had approximately the same number of patients.

Patients were assigned to hospital referral regions (HRR) based on zip-code of residence using a cross-walk available from the Dartmouth Atlas of Healthcare.[34] We assessed regional level factors that could be associated with the location of a for-profit hospital and use of brachytherapy including the presence of a state certificate of need (CON), two-year mammography rate, and radiation oncologist density for each HRR. The CON variable was used to assess the presence of policies that regulated the opening of new radiation facilities during the study period. We hypothesized that both two-year mammography rate, an indicator for screening practices for a given HRR, and radiation oncologist density might be associated with the use of RT because these regional characteristics may increase both the incidence rate of invasive breast cancer and access to RT.

Statistical Analysis

We used chi-square tests to determine the unadjusted association between hospital ownership and each covariate. We used hierarchical generalized linear models (HGLMs) with a logit link function to assess the unadjusted and adjusted relationship between hospital ownership and receipt of brachytherapy among patients who received RT.[35] HGLMs allowed us to account for the non-independence of outcomes by clustering patients within hospitals, which were clustered within HRRs. In all HGLMs, hospital and HRR were specified as random effects, while all other covariates were specified as fixed effects. We estimated an analogous model using receipt of any RT as our outcome in the full sample. Because RT can be considered optional in many women ≥70 years of age, we hypothesized that the effect of hospital ownership on receipt of any RT might be moderated by patient age. For this reason, we repeated this model with the addition of interaction terms between hospital ownership and age category and re-estimated the model separately among age groups with and without significant interactions. Finally, in order to determine whether any association between hospital ownership and receipt of any RT was driven primarily by the differential use of brachytherapy rather than WBI among older women, we estimated two additional models in which the outcomes were receipt of brachytherapy (versus no RT) and receipt of WBI (versus no RT). All data analyses were performed using SAS version 9.2 (SAS Institute Inc., Cary, NC); HGLMs were estimated using the GLIMMIX procedure.

RESULTS

Overview of Study Sample and Hospital Characteristics

Our sample included 35,118 beneficiaries who received BCS. The mean age was 74.2 (SD: 5.9) and less than 6% of our sample was above age 85. The majority of women were white (91.1%). About 72% of the sample received adjuvant RT, of whom 22,496 (88.9%) had

undergone BCS at a not-for-profit hospital and 2,816 (11.1%) at a for-profit hospital. Among women who received RT, there were significant differences between women receiving care at a for-profit compared to not-for-profit hospital with regard to race, residence in a metropolitan county, median household income, and receipt of a flu shot (Table 1). Patients from for-profit and not-for-profit hospitals were similar in all other patient characteristics.

Patients received care at 2,255 not-for-profit hospitals and 429 for-profit hospitals. Patients who received BCS at for-profit hospitals were more likely to receive surgery at lower surgical volume hospitals and reside in states without a CON for a radiation facility (63% of for-profit hospitals vs. 53% of not-for-profit hospitals, p<0.001). In addition, patients who received BCS at for-profit hospitals were more likely to reside in HRRs with a lower mammography rate and fewer radiation oncologists per capita.

Hospital Ownership and Receipt of Brachytherapy

Among beneficiaries receiving RT, 15.7% received brachytherapy. Women at for-profit hospitals who received RT were more likely to receive brachytherapy (20.2%) than women at not-for-profit hospitals (15.2%, adjusted odds ratio (OR): 1.50, 95% CI: 1.23–1.84, p<0.001, Table 2). Women who received BCS at higher surgical volume hospitals were also more likely to receive brachytherapy (OR for highest versus lowest quintile: 2.00, 95% CI: 1.57–2.53, p<0.001). In addition, patients who had left sided tumors, lymph node evaluation and screening mammograms were all more likely to have received brachytherapy (p<0.001). In contrast, patients receiving chemotherapy were less likely to receive brachytherapy.

Hospital Ownership and Receipt of Overall Radiation

There was no association between hospital ownership and the overall use of RT. That is, 73.1% of women undergoing BCS at a for-profit hospital subsequently received adjuvant RT, compared to 72.0% of women at not-for-profit hospitals (OR: 1.08, 95% CI: 0.97–1.20, p=0.18, Figure 1). However, the relation between hospital ownership and RT use varied across age groups. Among the oldest women (aged 80–94 years), those undergoing BCS at a for-profit hospital were more likely to receive any RT compared to women receiving care at a not-for-profit hospital (58.9% vs. 53.9%, OR: 1.22, 95% CI: 1.03–1.45, p=0.03, Figure 1). There was no significant difference in receipt of RT according to hospital profit status among women age 66–79 (78.1% vs. 78.8%, p=0.74)

The increased use of RT among older women at for-profit hospitals was associated primarily with receipt of brachytherapy. Specifically, women aged 80 and over receiving BCS at a for-profit hospital were more likely to receive brachytherapy (12.4% at for-profit vs. 8.0% at not-for-profit, OR for brachytherapy compared to no RT: 1.66, 95% CI: 1.18–2.34, p=0.003) while there was no relation between ownership status and the receipt of WBI (46.5% at for-profit vs. 45.9% at not-for-profit, OR for WBI vs. no RT: 1.14, 95% CI: 0.96–1.36, p=0.13).

DISCUSSION

We found that Medicare beneficiaries who underwent BCS at for-profit hospitals disproportionately received the more expensive and less proven brachytherapy over the less

expensive standard of care (WBI). Furthermore, older women (≥80) receiving BCS at for-profit hospitals received more RT overall, with this difference largely driven by the use of brachytherapy. Thus, older women received more aggressive care at for-profit hospitals, despite being less likely to benefit from RT.[27]

Several factors may have contributed to the increased use of brachytherapy for women who had undergone BCS at for-profit hospitals. Financial incentives may be one driving factor.[21,36,37] Prior studies have highlighted the high reimbursement for brachytherapy, suggesting that it is more revenue generating than the standard of care. [23,24,38] While high reimbursements do not necessarily equate to high profit margins, there has been concern that higher reimbursements have fueled the adoption of brachytherapy.[24,39–41] In fact, the Centers for Medicare and Medicaid Services reduction in reimbursement for brachytherapy in 2008 and 2010 generated important debate regarding the financial incentives and feasibility of offering brachytherapy. While we do not have actual profit margin estimates for brachytherapy in individual hospitals, our findings support previous reports suggesting that higher reimbursements may be contributing to the rapid adoption of brachytherapy.[39–41] In other cancer care settings, reduced reimbursement of chemotherapy has been associated with significant changes in patterns of chemotherapy use by oncologists.[42–44] In addition to direct financial incentives, leaders at for-profit hospitals may prefer adopting novel therapies as a way to build market share. Indeed, hospital advertising has been shown to promote more advanced technology as a means to attract patients.[45,46]

It is important to note that a driving factor in the adoption of brachytherapy is the attempt to enhance convenience and tolerability of treatment. Brachytherapy has the potential of delivering RT to patients who otherwise may not seek treatment due to concerns about treatment length and toxicity, and may be a reason for some older women to choose brachytherapy over standard RT. However, it is unclear why patient preferences for radiation modality would vary with hospital ownership. Given that women older than 80 years of age are least likely to benefit from radiation overall in terms of improvements in cancer control, our analysis suggests that brachytherapy may be increasing accessibility to RT overall, but not necessarily for women who benefit from it the most. [27,47] It is also notable that we found hospital volume to be strongly associated with receipt of brachytherapy; patients treated at the highest volume hospitals were twice as likely as those treated at the lowest volume hospitals to receive brachytherapy. It is possible that larger hospitals are more likely to have the resources needed to invest in new technologies. Hospital volume has been shown in past studies to be associated with newer surgical techniques in breast cancer[48–50] as well as prostate[51] and rectal[52] cancers.

Our study has important limitations. First, we defined hospital ownership as either not-for-profit or for-profit which does not distinguish hospital behavior that can exist in both profit settings.[53] We grouped hospitals listed as ‘Government’ or ‘Voluntary Non-profit’ as not-for-profit because of our hypothesis that for-profit hospitals in particular might adopt brachytherapy to a greater extent compared to other hospital types.[53] However, hospital behavior can align with financial incentives within not-for-profit organizations as well.[53,54] Therefore, coarse classification of ownership into either for-profit or not-for-profit may obscure financial factors that affect brachytherapy use. Second, we examined only Medicare

beneficiaries, who may not be representative of the patterns of brachytherapy utilization in younger patient populations or in patients with private insurance or no insurance. Third, we did not consider the decreases in the Centers for Medicare and Medicaid Services reimbursement for breast brachytherapy, the first of which took effect in January 2009.[24] However, our study illustrates the pattern of brachytherapy use when reimbursement was higher. While our results suggest that the year when treatment occurred did not affect receipt of brachytherapy, future work exploring how these changes affect brachytherapy utilization will add to our understanding of financial incentives and adoption of new technologies of cancer care. Fourth, our analysis does not account for provider factors such as physician reimbursement structures that may differ between hospitals. Our analysis does not examine the effect of ownership status of free-standing RT facilities which also provide RT for patients and may respond differently to financial incentives. Instead, we chose to use hospital ownership where BCS was performed because patients who are referred for RT eventually seek treatment at either hospital-based facilities, freestanding facilities, or seek no RT treatment. Thus, determining the effect of hospital ownership rather than RT facility ownership captures an earlier point in the clinical decision making process. Finally, it is important to acknowledge that the long-term risks and benefits of brachytherapy are still being defined; the current work is focused on the adoption of brachytherapy during a time when there was scant comparative evidence concerning either benefits or risks.

Our study extends the quality of surgical care literature by examining how hospital ownership affects the adoption of newer, more expensive cancer technologies. In addition, our study highlights the important role surgical providers may have in affecting post-surgical care decisions especially for older women for whom there exists considerable debate regarding the benefit of adjuvant RT.

Acknowledgments

The authors acknowledge the efforts of General Dynamics Information Technology (Buccaneer Computer Systems & Service, Inc.) Chronic Condition Data Warehouse, under contract with CMS.

Funding/support and role of the sponsor: Research reported in this publication was supported by the National Cancer Institute of the National Institutes of Health under Award Number R01CA149045. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health..

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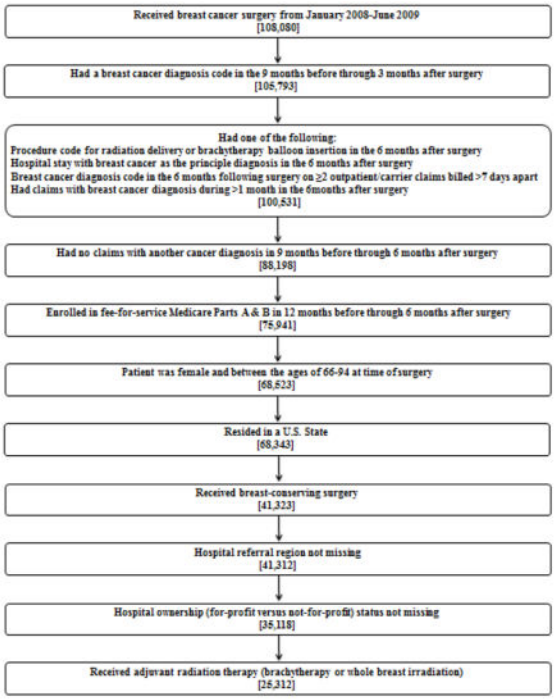
APPENDIX 1 Procedure and diagnosis codes used in analysis

	HCPCS	ICD-9 PROCEDURE	ICD-9 DIAGNOSIS
Breast-Conserving Surgery	19110, 19120, 19125, 19126, 19160, 19162, 19301, 19302	85.20, 85.21, 85.22, 85.23, 85.25,	
Whole Breast Irradiation	77402, 77403, 77404, 77406, 77407, 77408, 77409, 77411, 77412, 77413, 77414, 77416, 77418, 0073T, G0174		
Brachytherapy	77761, 77762, 77763, 77776, 77777, 77778, 77781, 77782, 77783, 77784, 77785, 77786, 77787, 77799, 0182T		
Tumor laterality	Breast-conserving surgery code with a HCPCS modifier indicating a left or right sided procedure, which is optionally included for procedures		
Axillary node dissection	19302, 38740, 38745, 38525, 38500	40.23, 40.51	
Chemotherapy	96400-96549, Q0083-Q0085, J9000-J9999, G0355-G0362, J8510, J8520, J8521, J8530, J8560, J8565, J8600, J8610, J8700	99.25	V58.1
Screening mammogram	76092, 77057, G0202, G0203		V76.1, V76.11, V76.12
Flu shot		90656, 90658, 90659, 90660, 90661, 90662, 90724	V04.81
Visit to primary care physician		99202, 99203, 99204, 99205, 99212, 99213, 99214, 99215, 99387, 99397	

APPENDIX 2 Sample Selection Algorithm



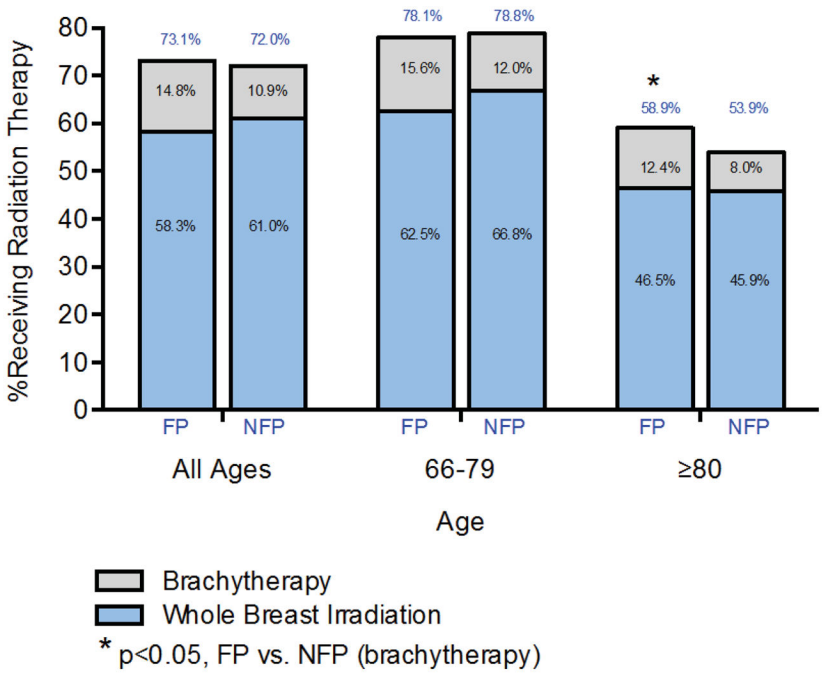


Figure 1.

Percent of women receiving any radiation therapy or brachytherapy based on age and hospital ownership. **NFP**: not-for-profit; **FP**: for-profit

Table 1

Characteristics of patients who received radiation therapy according to ownership of the hospital where breast-conserving surgery was performed.

	Non-profit		For-profit		
	N	%	N	%	p-value*
Total	22,496		2816		
Patient Characteristics					
Age at breast-conserving surgery					0.53
66–69	5964	26.5	765	27.2	
70–74	6673	29.7	834	29.6	
75–79	5209	23.2	619	22.0	
80–84	3412	15.2	428	15.2	
85–94	1238	5.5	170	6.0	
Race					<.001
White	20542	91.3	2517	89.4	
Black	1375	6.1	183	6.5	
Other	579	2.6	116	4.1	
Year of surgery					0.83
2008	14610	64.9	1823	64.7	
2009	7886	35.1	993	35.3	
Residence in metro county					0.001
Yes	18038	80.2	2330	82.7	
No	4458	19.8	486	17.3	
Income quintile					<.001
Q1 (≤$33,208)	4265	19.0	635	22.6	
Q2 ($33,209–$39,659)	4297	19.1	548	19.5	
Q3 ($39,661–$47,295)	4360	19.4	555	19.7	
Q4 ($47,300–$60,118)	4401	19.6	508	18.0	
Q5 (≥$60,124)	4422	19.7	467	16.6	
Unknown	751	3.3	103	3.7	

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	Non-profit		For-profit		
	N	%	N	%	p-value*
Clinical characteristics					
Comorbidity					0.72
0 conditions	12761	56.7	1584	56.3	
1–2 conditions	7995	35.5	1021	36.3	
≥3 conditions	1740	7.7	211	7.5	
Tumor laterality					0.41
Right-sided	9715	43.2	1227	43.6	
Left-sided	10056	44.7	1228	43.6	
Unknown	2725	12.1	361	12.8	
Axillary node dissection					0.06
No	6285	27.9	740	26.3	
Yes	16211	72.1	2076	73.7	
Chemotherapy					0.04
No chemotherapy	19721	87.7	2429	86.3	
Chemotherapy started in month prior through month after surgery	920	4.1	115	4.1	
Chemotherapy started in 31–365 days after surgery	1855	8.3	272	9.7	
Hospital admission**					0.96
No	19460	86.5	2435	86.5	
Yes	3036	13.5	381	13.5	
Screening mammogram**					0.06
No	5102	22.7	683	24.3	
Yes	17394	77.3	2133	75.8	
Flu shot**					0.02
No	9390	41.7	1242	44.1	
Yes	13106	58.3	1574	55.9	
Visit to primary care physician**					0.12
No	686	3.1	71	2.5	

	Non-profit		For-profit		
	N	%	N	%	p-value*
Yes	21810	97.0	2745	97.5	
Hospital characteristics					
Hospital volume**					<0.001
Q1 (1–7)	4170	18.5	855	30.4	
Q2 (8–14)	4284	19.0	862	30.6	
Q3 (15–22)	4347	19.3	445	15.8	
Q4 (23–38)	5013	22.3	338	12.0	
Q5 (39–142)	4682	20.8	316	11.2	
Health system characteristics					
State certificate of need for radiation facility					<0.001
No	11820	52.5	1773	63.0	
Yes	10676	47.5	1043	37.0	
HRR-level two-year mammography rate among female Medicare enrollees 67–69, in quintiles					<0.001
Q1 (50.1–59.7)	3941	17.5	793	28.2	
Q2 (59.8–62.4)	4400	19.6	706	25.1	
Q3 (62.4–64.9)	4652	20.7	468	16.6	
Q4 (65.0–68.4)	4762	21.2	441	15.7	
Q5 (68.4–76.1)	4741	21.1	408	14.5	
Radiation oncologist density per 100,000 residents, in quintiles					<0.001
Q1 (0.2–1.0)	4397	19.6	688	24.4	
Q2 (1.0–1.1)	4078	18.1	660	23.4	
Q3 (1.1–1.2)	4531	20.1	624	22.2	
Q4 (1.2–1.4)	4818	21.4	293	10.4	
Q5 (1.4–2.5)	4672	20.8	551	19.6	

* P-value is for chi-square test of the association between each covariate and profit status

** In year prior to breast-conserving surgery

*** Hospital volume is defined as the number of patients in our sample who received breast-conserving surgery at each hospital during the study period

Surgery. Author manuscript; available in PMC 2015 May 01.

Table 2

Associations between patient, clinical, and health system characteristics and the receipt of brachytherapy. Adjusted for patient, clinical, and health system characteristics

	Percent Receiving Brachytherapy	Unadjusted				Adjusted*			
		OR	95% CI		P-value	OR	95% CI		P-value
Hospital characteristics									
Hospital profit status					0.01				<0.001
Non-profit	15.2	1.00	--	--		1.00	--	--	
For-profit	20.2	1.28	1.06	1.55		1.50	1.23	1.84	
Hospital volume**					<0.001				<0.001
Q1 (1–7)	9.1	1.00	--	--		1.00	--	--	
Q2 (8–14)	13.2	1.40	1.15	1.69		1.38	1.13	1.67	
Q3 (15–22)	16.6	1.98	1.61	2.43		2.02	1.64	2.50	
Q4 (23–38)	20.0	2.21	1.79	2.72		2.24	1.80	2.77	
Q5 (39–142)	19.6	1.93	1.53	2.44		2.00	1.57	2.53	
Patient characteristics									
Age at BCS					0.52				
66–69	16.0	1.00	--	--					
70–74	15.6	0.99	0.89	1.09					
75–79	15.8	0.97	0.86	1.08					
80–84	15.7	0.90	0.80	1.03					
85–94	15.3	0.91	0.76	1.09					
Race					0.02				0.06
White	15.9	1.00	--	--		1.00	--	--	
Black	13.2	0.77	0.65	0.92		0.81	0.67	0.97	
Other	15.0	0.99	0.77	1.27		1.04	0.80	1.33	
Year of surgery					0.53				
2008	15.7	1.00	--	--					
2009	15.8	0.97	0.90	1.06					
Residence in metro county					0.51				
Yes	16.4	1.00	--	--					

	Percent Receiving Brachytherapy	Unadjusted				Adjusted*			
		OR	95% CI		P-value	OR	95% CI		P-value
No	12.9	0.96	0.84	1.09					
Income quintile					**0.29**				
Q1 (≤$33,208)	15.3	1.00	--	--					
Q2 ($33,209–$39,659)	14.7	0.96	0.84	1.10					
Q3 ($39,661–$47,295)	16.3	1.05	0.92	1.20					
Q4 ($47,300–$60,118)	16.2	1.02	0.89	1.18					
Q5 (≥$60,124)	15.4	0.95	0.82	1.11					
Unknown	19.9	1.21	0.97	1.51					
Clinical characteristics									
Comorbidity					0.59				
0 conditions	15.6	1.00	--	--					
1–2 conditions	16.0	1.03	0.95	1.12					
≥3 conditions	15.4	0.96	0.83	1.12					
Tumor laterality					<0.001				<0.001
Right sided	15.6	1.00	--	--		1.00	--	--	
Left sided	16.7	1.10	1.02	1.20		1.11	1.02	1.21	
Unknown	12.9	0.81	0.71	0.93		0.83	0.72	0.96	
Axillary node dissection					<0.001				<0.001
No	11.6	1.00	--	--		1.00	--	--	
Yes	17.3	1.46	1.32	1.60		1.52	1.38	1.68	
Chemotherapy (composite)					<0.001				<0.001
No chemotherapy	16.3	1.00	--	--		1.00	--	--	
Chemotherapy started in month prior through month after surgery	7.2	0.33	0.25	0.43		0.32	0.24	0.41	
Chemotherapy started in 31–365 days after surgery	13.8	0.73	0.63	0.84		0.70	0.61	0.82	
Hospital admission***					0.04				
No	15.9	1.00	--	--					
Yes	14.3	0.89	0.79	1.00					
Screening mammogram***					<0.001				<0.001
No	13.4	1.00	--	--		1.00	--	--	
Yes	16.4	1.45	1.32	1.60		1.44	1.30	1.59	

	Percent Receiving Brachytherapy	Unadjusted				Adjusted*			
		OR	95% CI		P-value	OR	95% CI		P-value
Flu shot* **					0.34				
No	15.4	1.00	--	--					
Yes	16.0	1.04	0.96	1.13					
Visit to PCP* **					0.03				
No	12.0	1.00	--	--					
Yes	15.8	1.32	1.03	1.71					
Health system characteristics									
State CON for radiation facility					0.09				
No	17.5	1.00	--	--					
Yes	13.6	0.85	0.71	1.02					
HRR-level two-year mammography rate among female Medicare enrollees 67–69, in quintiles					0.04				0.007
Q1 (50.1–59.7)	17.1	1.00	--	--		1.00	--	--	
Q2 (59.8–62.4)	17.2	1.05	0.76	1.44		1.04	0.76	1.44	
Q3 (62.4–64.9)	16.3	0.92	0.67	1.27		0.89	0.64	1.23	
Q4 (65.0–68.4)	16.1	0.80	0.58	1.10		0.75	0.55	1.04	
Q5 (68.4–76.1)	12.0	0.67	0.49	0.92		0.62	0.45	0.85	
Radiation oncologist density per 100,000 residents, in quintiles					0.26				
Q1 (0.2–1.0)	16.6	1.00	--	--					
Q2 (1.0–1.1)	17.2	0.92	0.69	1.23					
Q3 (1.1–1.2)	17.7	0.85	0.63	1.16					
Q4 (1.2–1.4)	15.3	0.84	0.63	1.13					
Q5 (1.4–2.5)	12.0	0.70	0.51	0.96					

* Adjusted for the following health system characteristics: state certificate of need (CON), HRR level 2-year mammography rate in quintiles, and radiation oncologist density per 100,000 enrollees

** Hospital volume is defined as the number of patients in our sample who received breast-conserving surgery at each hospital during the study period

*** In year prior to breast-conserving surgery