Personalized Medicine When Physicians Induce Demand

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Abstract: Although personalized medicine has the potential to reduce costs, it's actual impact will depend on how information affects physicians' decisions in settings where they face incentives to prescribe costlier treatments. We show that when physicians face incentives to induce demand, the introduction of a test will increase overall treatment rates. We show that breast cancer patients treated in freestanding radiotherapy clinics, where physicians face stronger incentives to induce demand, are more likely to receive a costly, low value form of radiotherapy called intensity modulated radiation therapy (IMRT). The difference in the use of IMRT between freestanding and hospital-based centers is the greatest for patients most likely to benefit from it. These results highlight the challenge of maximizing the benefit of tests that imperfectly predict patients' ability to benefit from a treatment in an environment where physicians' compensation is tied to the volume of treatments they provide.

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Introduction

Advances in genetics and artificial intelligence promise to launch an era of "personalized medicine." Diagnostics and algorithms will help doctors distinguish between patients who are and are not likely to benefit from a treatment. Discussions of the impact of personalized medicine on treatment patterns and costs often proceed as if physicians will use information in a socially optimal manner. For example, proponents of personalized medicine claim that it will reduce health care spending (for example, PhRMA 2015) by identifying patients unlikely to benefit from costly therapies. However, the mechanism by which this will occur is unclear. Physicians often face incentives to provide costly treatments. It seems just as likely that giving physicians additional information could lead to increases in the share of patients who are treated. Many tests do not definitively identify patients who will and will not benefit from a treatment. Instead, they provide another prognostic factor to consider alongside the standard clinical variables (Hunter et al. 2016).

Using the standard physician-induced demand model, we show how the introduction of a test that predicts patients' ability to benefit from treatment will lead to an increase in the share of patients receiving the treatment when physicians face financial incentives to provide it. Also, treatment rates for patients most likely to benefit from treatment will be more responsive to incentives.

We evaluate the interaction between patients' ability to benefit from treatment and financial incentives using the case of intensity modulated radiation therapy (IMRT) for breast cancer. Patients differ in their ability to benefit from IMRT, based on whether the tumor is in the left or right breast, and physicians differ in their incentives, based on whether they practice in a freestanding or hospital-based clinic. We find that IMRT use is much higher among women treated at freestanding clinics. Consistent with theory, the difference in IMRT use is greater among women more likely to benefit from IMRT use.

Our results suggest that the realized efficiency gains from the introduction of personalized medicine tests will depend on the financial incentives facing providers. In general, we expect that the introduction of tests will increase treatment rates and costs.

In related work, Dinan et al. (2015) report that receipt of the 21-gene recurrence score assay, a test which predicts breast cancer patients' ability to benefit from chemotherapy, was not associated with lower rates of use of chemotherapy among breast cancer patients. However, only 10% of the patients in the sample received the test. Cross sectional comparisons may be biased by other patient characteristics related to the ability to benefit from chemotherapy and the receipt of the test. In our case, tumor laterality is readily observable to all physicians, and so estimates of the impact of the information are unbiased by unobserved factors related to providers' decisions to obtain it.

A model of treatment choice

We modify the standard physician-induced demand model to show how allowing physicians to set different treatment thresholds for different patient groups affects the overall treatment rate and how financial incentives influence the relative treatment rates in each group.

To review, in the standard model physician utility is a function of income and the level of inducement: $u(y,i)$. Inducement raises income via its impact on the share of patients treated, but physicians pay a psychic cost for acting against their best assessment of patient and societal welfare. For simplicity, we assume physicians' labor supply is fixed. Income is $y = rx(i)$, where r is the reimbursement rate and $x(i)$ describes how the share of patients treated varies with inducement. Partial derivatives are $u_y > 0$, $u_i < 0$, $x_i > 0$ and $u_{yy} < 0$, $u_{ii} < 0$, and $x_{ii} < 0$. We assume additive separability: $u_{yi} = 0$

Assume there are two patient types who differ in their ability to benefit from treatment. High-benefit types have utility $u^H(y,i)$ and low-benefit types have utility $u^L(y,i)$, where

$$u^H(y,0) = u^L(y,0)$$

and the disutility of inducing demand among low-benefit patients increases at a faster rate:

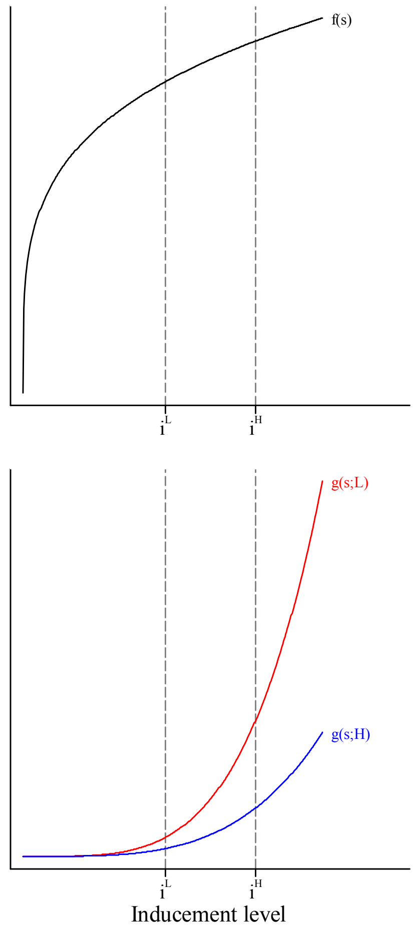
$$u_i^H < u_i^L < 0,$$
$$u_{ii}^H < u_{ii}^L < 0.$$

If physicians can set different inducement levels for high- and low-benefit patients, the utility-maximizing inducement level is higher for high-benefit patients: $i^H \geq i^L$. The utility-maximizing threshold for low-benefit patients is defined by $u_y^L = -u_i^L$ (see Figure 1). At the utility-maximizing level of inducement for low-benefit patients, the marginal utility of income exceeds the marginal utility of inducement for high-benefit patients,

$$-u_y^L(i^L) = u_y^H(i^L) > -u_y^H(i^L).$$

The first inequality holds because physicians' marginal utility of income does not depend on whether they are treatment high- or low-benefit patients, and the second inequality holds because because $u_i^H < u_i^L$. Since physician utility for high-benefit patients is increasing at i^L, then $i^H \geq i^L$.

Figure 1: Utility maximizing inducement levels



If physicians cannot distinguish between high- and low-benefit patients, they maximize $u^H(y,i)+u^L(y,i)$, assuming that half of patients are each type. Let i^M indicate the level of inducement that maximizes this sum.

A test that allows physicians to distinguish between high- and low-benefit patients will cause the share of patients receiving the most costly treatment to rise: $\frac{1}{2}i^L+\frac{1}{2}i^H>i^M$. i^M will fall in the interval between i^L and i^H and is defined by

$$u_y^H(y,i)x_ir+u_i^H(y,i)=-[u_y^L(y,i)x_ir+u_i^L(y,i)].$$

At i^M, physicians' marginal utility for low-benefit patients is falling (the term in the brackets is negative].

Since $u(\cdot)$ is single-peaked, utility for low-benefit patients is declining for $i>i^L$ and utility for high-benefit patients is increasing for $i<i^H$. In the interval between i^L and i^H

physicians' marginal utility for low-benefit patients decreases at a faster rate than physicians' marginal utility for high-benefit patients increases because $0 > u_{ii}^{H} > u_{ii}^{L}$ for all i (i.e., u_{ii}^{L} is more negative for a given i). Therefore, physicians' marginal utilities for high- and low-benefit patients must intersect (which defines i^{M}) at a point in the interval between i^{L} and $\frac{1}{2}i^{L} + \frac{1}{2}i^{H}$. A similar argument can be used to show that the treatment rate, x, is higher when physicians can tailor treatment to patients' type.

The impact of a change in the reimbursement rate on inducement is ambiguous. If the income effect is strong enough, an increase in reimbursement rates could lead to a decrease in inducement. Regardless of whether an increase in the reimbursement rate increases or decreases inducement, inducement levels for high-benefit patients are more responsive to fees. The terms u_{ii}^{H} and u_{ii}^{L} enter positively in the denominators of the derivatives of i^{H} and i^{L} with respect to the reimbursement rate (see equation 2 in McGuire and Pauly). The denominator will be larger, and the derivative smaller, for low-benefit patients since $u_{ii}^{H} < u_{ii}^{L}$.

Clinical background

Women with early stage breast cancer are typically offered the choice between mastectomy and breast conserving surgery (also known as lumpectomy). Following breast conserving surgery, where surgeons remove visible masses of tumor cells, most patients undergo radiation therapy to kill any remaining tumor cells. Therapy is delivered on an outpatient basis. Conventional external beam radiation therapy can damage healthy cells near the target site, leading radiation oncologists to seek methods of delivering radiation that spare the tissue surrounding the target. Unlike conventional beam radiation, IMRT uses sophisticated treatment planning software to ensure that the target area receives a consistent, uniform dose while minimizing the delivery of radiation to nearby tissue. IMRT is commonly used as a primary therapy for head and neck cancer and prostate cancer. While IMRT reduces the delivery of high dose radiation to critical anatomic structures, it also "scatters" more low dose radiation compared to conventional radiotherapy (Shubert et al. 2011; Zhang et al. 2011). However, the net effect is thought to favor IMRT.

Several randomized trials have compared IMRT to conventional radiotherapy in breast cancer patients benefits (Mukesh et al. 2013; Pignol et al. 2008). They found that patients treated with IMRT were less likely to experience cosmetic side effects and self-limiting skin peeling and irritation but had similar quality of life, tumor recurrence rates, and survival rates. Based on the lack of evidence that IMRT is associated with clinically significant benefits, the American Society for Radiation Oncology (2013) recommends against routine use of IMRT in breast cancer patients following breast conserving surgery. Medicare spending is $6,000 to $8,000 higher for breast cancer patient who receive IMRT compared to conventional radiotherapy (Roberts et al. 2013; Smith et al. 2011).

Radiotherapy risks damaging the heart. The risk is higher for women with tumors in the left breast. For this reason, the value of IMRT is higher for women with left-sided tumors. Some Medicare claims processors and Medicare Advantage plans include the following language in their IMRT coverage policies, "Indications will include some left breast tumors due to risk to immediately adjacent cardiac and pericardial structures, though it would only rarely if ever be medically necessary for tumors of the right breast." Even for women with left-sided tumors, the value of IMRT is questionable for most patients. The increased use of relatively inexpensive techniques and technologies, like breath-holding or shields, has probably reduced the exposure of the heart to radiation (Recht 2017).

For the sake of simplicity and tractability, we assumed that physicians' utility for high-benefit patients does not depend on the inducement rate for low benefit patients and vice versa. There are two ways in which they may interact.

First, the disutility of inducing demand for high-benefit patients may depend on the level of inducement for low-benefit patients. Following McGuire and Pauly, who model how physicians chose treatment rates when there are two payers, we assume they are independent.

Second, an increase in the inducement level for low benefit patients will affect income and the marginal benefit of additional inducement for high-benefit patients via its impact on income. We ignore this second-order effect.

Applicability of the model to IMRT

Physicians provide IMRT to patients with breast cancer as well as other tumor types. For prostate and head and neck cancer, IMRT is the standard of care. An increase in reimbursement will increase physician income, both via its impact on revenues for breast cancer patients and via its impact on revenues for patients with other types of cancer. Use of IMRT in prostate and head and neck cancer patients will be much less responsive to reimbursement rates. Consequently, an increase in the reimbursement rate for IMRT will increase physicians' incomes independent of its effect on treatment rates and revenue for breast cancer patients.

We cannot test the impact of the introduction of a personalized medicine test directly. In our application, patient type is readily observable. However, we can study how the impact of patient type varies based on physicians' incentive to induce demand. The fact that tumor laterality is readily observable is an advantage in that we do not have to model or address physicians' decisions to invest in the information, which would be the case in settings where new tests have been introduced.

Physicians' treatment setting

Cancer patients can receive radiotherapy at freestanding clinics, most of which are owned by the radiation oncologists who practice there, or hospital-based clinics. Some hospitals employ radiation oncologists, and in recent years many hospitals have purchased radiation oncology groups. However, during the period covered by our study, most hospital clinics were staffed by radiation oncologists in independent groups. In some cases hospitals and independent radiation oncology groups co-manage a radiation oncology clinic.

Delivery of IMRT is a complex, multi-step process that includes treatment planning, physician management, imaging procedures, and treatment delivery. Clinics bill separate Current Procedural Terminology (CPT) codes for each step. Some are billed only once, others are billed on a recurring basis. According to online patient education materials, patients typically undergo 25 to 40 sessions. Radiology clinics bill a code for treatment delivery for each session. There is no professional fee associated with the code, but the facility fee for treatment delivery in a freestanding clinic is approximately $500, accounting for a substantial share of the total revenues associated with IMRT. Medicare sets facility fees to coverage average costs. The difference between average and marginal costs may be especially large for capital-intensive services like IMRT. The fee for treatment delivery of conventional beam radiation therapy is around $100.

Radiation oncologists in independent practices receive a salary and possibly a bonus tied to the professional fees they generate. Radiation oncologists who are owners also receive a share of the group's profits. Radiology groups whose physicians staff hospital clinics bill for the professional fees only. Groups that co-manage a hospital clinic may also receive a management fee that is set independently of the volume of care the physicians provide. Freestanding radiation clinics and hospitals that employ radiation oncologists bill for both professional and facility fees. They cannot pay facility fees directly to physicians based on the volume of care they provide (it would violate Medicare anti-kickback regulations). Instead, facility fees augment the profits that are distributed to owners. For this reason, physicians in freestanding clinics may face extra incentives to provide IMRT instead of conventional radiotherapy compared to physicians practicing in other types of settings.

Studies on how physician incentives affect the use of IMRT have mostly focused on the treatment of prostate cancer. A 2010 *Wall St. Journal* article (Carreyrou and Tamman 2010) described how companies like Urorad Healthcare help urology practices set-up their own IMRT centers. According to the article, Integrated Medical Professionals, a large urology group in New York, owns 11 linear accelerators. Half the patients treated by the practice undergo IMRT. Three studies (Bekelman et al. 2013; General Accounting Office 2013; Mitchell 2013) have found that the acquisition of IMRT equipment by a urology group increases the share of prostate cancer patients receiving IMRT versus prostatectomy or other treatments by about 15% percentage points. Despite using different patient samples and methods for identifying self-referring practices, the studies were remarkably consistent in their findings. Studies examining the determinants of radiotherapy treatment patterns among breast cancer patients have found that patients treated in freestanding clinics are substantially more likely to receive IMRT (Roberts et al. 2013; Smith et al. 2011). It is unclear to what degree these differences are attributable to unobserved patient characteristics.

In other clinical settings, a number of studies have shown that when physicians assume ownership stakes in facilities or equipment, their procedure volume rises (Baker 2010; Barro et al. 2006; Hollenbeck et al. 2010; Hollingsworth et al. 2010a; 2010b; 2011; Iizuka 2007; 2012; Mitchell 1992; 2005; 2008; 2010l, Nallamothu et al. 2007; Shreibati and Baker 2012). These results strongly suggest that the incentives inherent in physician ownership affect physicians' treatment decisions, though there are alternative explanations. Physicians' responses could reflect the convenience of having equipment on-site, or physicians may purchase ownership stakes in anticipation of planned changes in practice patterns. For example, orthopedic surgeons who want to specialize in outpatient surgeries may buy ownership stakes in ambulatory surgery centers. Physicians who believe that a treatment is effective may be more likely to take an ownership stake in the facility or equipment necessary to deliver it.

The setting for our study differs in some respects from that of previous studies of physician ownership. Most previous studies examine changes or differences in the volume of a particular procedure. In our case, all patients receive treatment, either IMRT or another form of radiotherapy. This feature facilitates identification because we observe patients who do and do not receive the treatment in question.

Also, it is safe to assume that by the start of our study period, 2008, all radiation therapy clinics had the capability to perform IMRT, even if they never used it in breast cancer patients. Variation in use cannot be explained in terms of differences in convenience or availability. Radiation oncologists may specialize in the treatment of specific tumor types, but they do not specialize in the delivery of IMRT. Comparisons between freestanding and hospital-based clinics are not biased by differences in the degree of specialization in particular types of radiotherapy.

Data

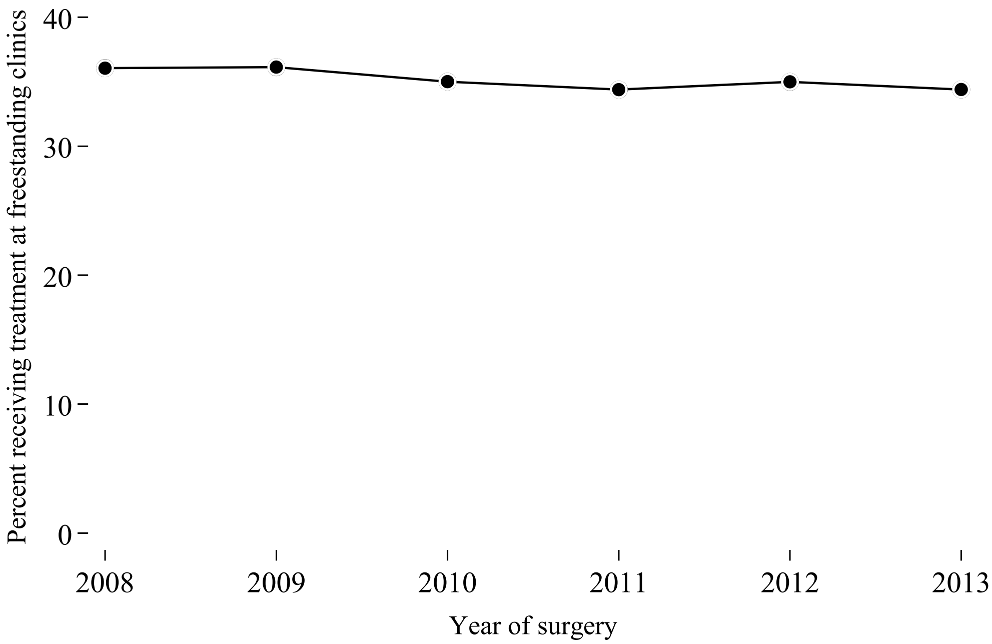
Using SEER-Medicare data, we estimate the impact of clinic type (freestanding versus hospital-based) and tumor laterality on the receipt of IMRT. SEER-Medicare includes tumor registry records from regional SEER tumor registries linked with Medicare claims for Medicare-eligible beneficiaries. The SEER registries capture 100% samples of cancer patients from California, Georgia, Iowa, Hawaii, Utah, Kentucky, Louisiana, New Mexico, Connecticut, Detroit, and Seattle. From SEER Medicare we selected a sample of women who were diagnosed with early or regional stage breast cancer between 2008 and 2013 (the latest year available), were 66 years of age or older, were continuously enrolled in fee-for-service Medicare in the 24 month window centered on the diagnosis date, underwent breast conserving surgery, and received post-operative radiotherapy. Details are presented in Table 1.

Table 1: Sample construction

Included	Excluded	Criteria
37,347		Had breast conserving surgery within 90 days of diagnosis between 2008 and 2013
29,010	8,337	Had a claim for radiotherapy
23,285	5,725	Age ≥66 and continuously enrolled in Medicare
23,252	33	Stage at diagnosis known
23,123	129	Early or regional stage (non-metastatic)

The primary outcome is the receipt of IMRT versus another form of radiation therapy. The primary independent variable is provider type. We classified patients as receiving treatment at a freestanding clinic if the patients' initial radiotherapy claim appeared in the National Claims History file (freestanding clinics bill as physician offices). All other patients were classified as treated at hospital-based clinics, which bill as hospital outpatient departments. We used a similar approach to categorize the type of provider where the patient received surgery. We further categorized hospital radiotherapy clinics based on the type of hospital using the hospital characteristics file included with the SEER-Medicare data. Figure 2 shows that the share of patients receiving treatment at freestanding clinics did not change over the study period.

Figure 2: The share of patients treated at freestanding clinics

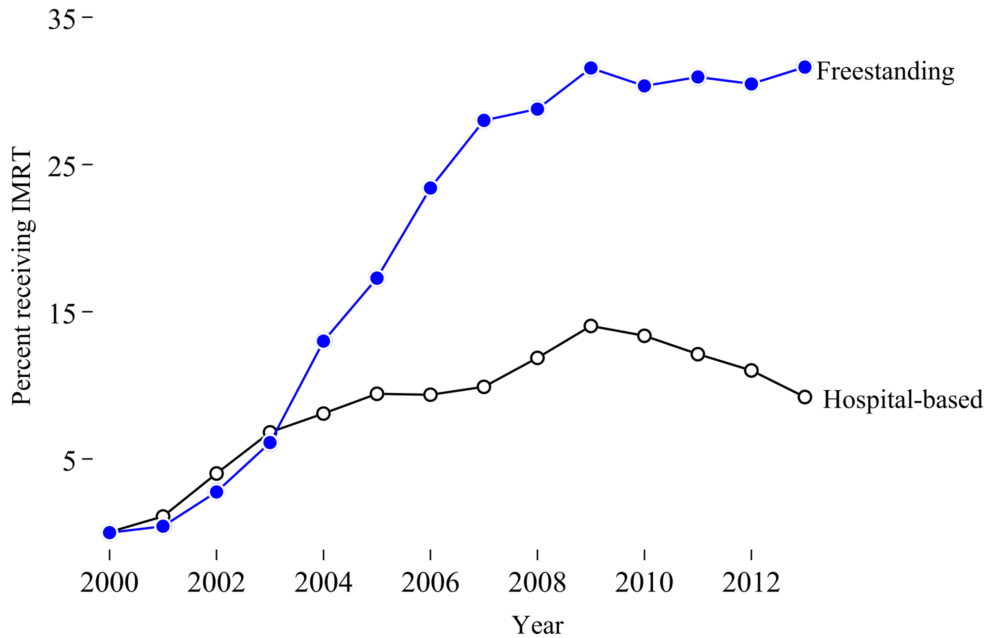


Trends in treatment patterns

Figure 2 shows the proportion of patients receiving IMRT by provider type. For this descriptive analysis, we include women diagnosed after 2000.

Initially, patients in hospital-based clinics were slightly more likely to receive IMRT. Clinics had to spend over $2,000,000 to acquire the equipment to provide IMRT, and hospitals may have an advantage over freestanding clinics in financing investments in costly capital equipment. By 2008 29% patients treated in freestanding clinics received IMRT compared with only 12% percent in hospital clinics. We do not have data on the date when clinics acquired the capability to perform IMRT. IMRT quickly became the standard of care for prostate and head and neck tumors. Based on conversations with radiation oncologists, we believe that nearly all clinics had the capability to delivery IMRT by 2008 if not earlier.

Figure 3: The share of patients receiving IMRT



Patients who did not receive IMRT either underwent conventional beam radiation or brachytherapy. Brachytherapy requires the implantation of a catheter to deliver the radioactive seeds. In breast cancer patients the implantation typically occurs during surgery, which proceeds radiotherapy, and so radiation oncologists have less influence over the use of brachytherapy. The share of patients receiving brachytherapy was 10.6% in freestanding clinics and 10.4% in hospital-based clinics.

Regression-adjusted differences

We use logistic regression to estimate differences in the receipt of IMRT between freestanding and hospital-based clinics, adjusted for observable patient characteristics. This model and all others are adjusted for clustering at the radiology clinic level. Table 2 presents sample means. Most of the markers of disease severity – tumor size, whether cancer is detectable in the lymph nodes near the breast, and whether the stage at diagnosis is local or regional – are similar between patients treated in hospital-based and freestanding clinics. Women treated in hospital-based clinics are more likely to have estrogen-receptor-positive tumors. Women with estrogen-receptor-positive tumor have a better prognosis. Most of the other variables are self-explanatory.

Table 2: Patient characteristics

		Radiotherapy clinic type		
	All patients	Freestanding	Hospital	P-value
		N (%)		
Freestanding clinic	35.2	100.0	0.0	
Left-side tumor	50.6	50.2	50.8	0.34
Tumor size >2 cm	22.5	22.9	22.2	0.21
Positive lymph nodes	15.6	15.9	15.4	0.39
Local stage	83.3	82.9	83.5	0.24
ER positive	86.4	85.2	87.0	<0.01
Age				0.49
65-74	56.0	56.5	55.7	
75-84	37.7	37.3	37.9	
85+	6.3	6.2	6.4	
Race				<0.01
White	88.1	88.5	87.9	
Black	6.4	5.6	6.9	
Asian	1.9	2.0	1.8	
Hispanic	1.1	1.2	1.0	
Other	2.5	2.7	2.4	
Region				<0.01
Pacific	38.6	45.6	34.8	
East	43.8	38.3	46.8	
North	11.5	9.1	12.8	
Other	6.1	7.1	5.7	
Medicaid coverage	8.8	9.7	8.4	<0.01
Rural/less urban	12.3	14.0	11.4	<0.01
Year				0.41
2008	16.6	17.1	16.4	
2009	17.0	17.5	16.8	
2010	16.8	16.7	16.8	
2011	17.0	16.7	17.2	
2012	16.4	16.3	16.5	
2013	16.1	15.8	16.3	
N	23,123	8,132	14,991	

ER positive: estrogen receptor positive tumor.

The first column of Table 3 displays marginal effects from a probit regression. The dependent variable equals 1 if the patient received IMRT and 0 if the patient received another form of radiotherapy. Standard errors are clustered at the clinic level. Controlling for patient characteristics, patients who received radiotherapy in freestanding clinics at 18 percentage points more likely to receive IMRT.

The proportion of patients receiving IMRT is 7 percentage points higher among patients with tumors in the left breast. Most of the other patient characteristics have only small, non-significant effects.

Table 3: Marginal effect on the likelihood of receiving IMRT from probit regressions

	Probit			IV probit			IV probit, patients who received surgery in hospitals only		
				Marginal effect (95% CI)					
Freestanding clinic	0.18	(0.11, 0.25)	**	0.17	(0.03, 0.32)	*	0.16	(0.03, 0.30)	*
Left-side tumor	0.07	(0.05, 0.09)	**	0.08	(0.06, 0.10)	**	0.08	(0.06, 0.10)	**
Tumor size >3 cm	0.00	(-0.02, 0.01)		0.00	(-0.01, 0.02)		0.01	(-0.01, 0.03)	
Positive lymph nodes	0.00	(-0.05, 0.05)		0.00	(-0.05, 0.04)		0.00	(-0.05, 0.05)	
Local stage	-0.01	(-0.06, 0.03)		-0.02	(-0.07, 0.02)		-0.02	(-0.07, 0.03)	
ER positive	0.00	(-0.02, 0.02)		0.01	(-0.01, 0.02)		0.01	(-0.01, 0.03)	
Age 75-84	0.01	(-0.00, 0.02)		0.01	(0.00, 0.02)	*	0.01	(0.00, 0.02)	*
Age 85+	-0.02	(-0.04, 0.01)		0.00	(-0.03, 0.02)		-0.01	(-0.03, 0.02)	
Black	0.03	(-0.01, 0.07)	+	0.05	(0.01, 0.08)	**	0.04	(-0.00, 0.08)	+
Asian	-0.03	(-0.08, 0.02)		-0.08	(-0.15, -0.01)	*	-0.06	(-0.14, 0.01)	+
Hispanic	-0.03	(-0.11, 0.04)		-0.06	(-0.12, 0.00)	+	-0.05	(-0.12, 0.02)	
Other	-0.04	(-0.09, 0.01)		-0.07	(-0.13, -0.02)	**	-0.08	(-0.14, -0.02)	*
Medicaid coverage	-0.03	(-0.06, -0.00)	*	-0.03	(-0.06, 0.00)	+	-0.04	(-0.07, -0.01)	*
Rural/less urban	-0.06	(-0.11, -0.01)	*	-0.06	(-0.11, -0.00)	*	-0.07	(-0.12, -0.01)	*
2009	0.02	(0.00, 0.05)	*	0.02	(0.00, 0.05)	*	0.02	(-0.00, 0.04)	+
2010	0.02	(-0.01, 0.04)		0.02	(-0.01, 0.04)		0.01	(-0.02, 0.03)	
2011	0.01	(-0.02, 0.04)		0.01	(-0.02, 0.04)		0.00	(-0.03, 0.03)	
2012	0.00	(-0.03, 0.04)		0.00	(-0.03, 0.04)		-0.01	(-0.04, 0.03)	
2013	-0.01	(-0.04, 0.03)		-0.01	(-0.04, 0.03)		-0.02	(-0.05, 0.02)	
N	23,123			23,123			19,092		

+p<0.10;*p<0.05;**p<0.01

We performed an instrumental variables analysis to confirm that differences in the receipt of IMRT are not biased by unobserved patient characteristics. We use the type of provider where patients received surgery as an instrument. Patients receive surgery in one of three types of providers 1) freestanding surgery centers, 2) hospitals with radiation oncology clinics, and 3) hospitals that do not have radiation oncology clinics. We hypothesized that patients who receive surgery in hospitals with radiation oncology clinics will be more likely to receive radiotherapy at a hospital-based clinic. The identifying assumption is that the patient characteristics that predict whether patents receive IMRT (conditional on observables) do not predict what the type of provider at which patients receive surgery. These characteristics could include clinical characteristics like the proximity of the tumor to healthy vital tissues that could be damaged by radiation exposure and personality traits like a preference for advanced technology.

Figure 3 shows the proportion of patients who receive post-operative radiotherapy by surgery provider type. Compared to patients who receive surgery in freestanding surgery centers and patients who receive surgery in hospitals that do not offer radiotherapy, patients who receive surgery in hospitals that do offer radiotherapy are about 4 and 3 percentage points more likely to receive post-operative radiotherapy. However, these differences are small in percentage terms given that 78% of patients receive post-operative radiotherapy.

Figure 4: Proportion of patients undergoing post-operative radiotherapy by surgical provider type

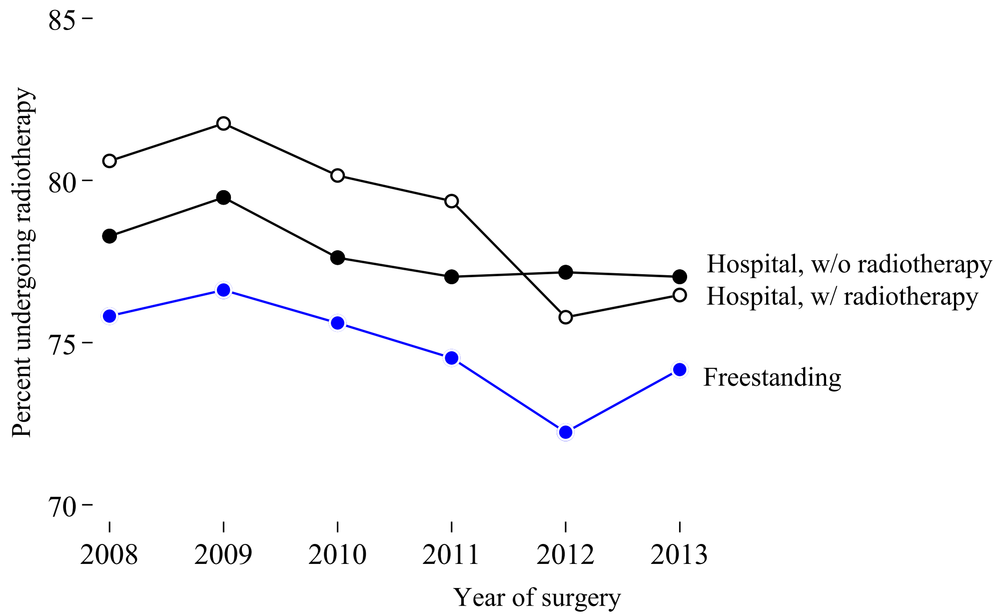


Table 4 shows patient characteristics by surgery provider type (as opposed to radiation therapy provider type). The exclusion restriction would be violated if patients with unobservable tumor characteristics related to their ability to benefit from IMRT were more or less likely to receive surgery in hospitals with radiotherapy clinics. Patients treated at freestanding and hospital-based clinics look fairly similar, at least based on observable characteristics. What differences do exist suggest that patients in freestanding clinics have worse prognoses. However, the tumor characteristics that is most closely related to patients' ability to benefit from IMRT, tumor laterality, does not differ.

Table 4: Patient characteristics by surgery provider type

	Surgery provider type			
	Freestanding	Hospital without radiotherapy	Hospital with radiotherapy	P-value
		%		
Left-side tumor	50.3	50.8	50.5	0.85
Tumor size >3 cm	25.2	22.1	21.4	<0.01
Positive lymph nodes	20.8	14.2	15.0	<0.01
Local stage	77.8	84.7	83.8	<0.01
ER positive	85.4	87.3	85.0	<0.01
N	4,031	6,066	13,026	

Table 5 shows the proportion of patients receiving radiotherapy in a freestanding clinic and IMRT across surgery provider types. Among patients receiving surgery in a freestanding surgery center, 39.1% receive radiotherapy in a freestanding clinic. Among patients receiving surgery in hospitals without a radiotherapy clinic, 68.3% received radiotherapy in a freestanding clinic compared to only 18.5% of patients who received surgery in a hospital with a radiotherapy clinic. Patients treated at freestanding radiotherapy centers are more likely to receive IMRT across all survey provider types. Overall, patients treated at hospitals without radiotherapy centers are more likely to receive IMRT, reflecting the fact that 68.3% receive radiotherapy in freestanding clinics.

Table 5: Receipt of IMRT

			Surgery provider type					
Radiotherapy facility	All		Freestanding		Hospital without radiotherapy		Hospital with radiotherapy	
	Percent receiving IMRT, Number receiving IMRT/Total							
Freestanding clinic	35.2%	8,132/23,123	39.1%	1,578/4,031	68.3%	4,143/6,066	18.5%	2,411/13,026
IMRT	18.5%	4,281/23,123	17.3%	698/4,031	25.6%	1,554/6,066	15.6%	2,029/13,026
IMRT by provider type								
Freestanding	30.6%	2,489/8,132	29.0%	457/1,578	31.8%	1,319/4,143	29.6%	713/2,411
Hospital	12.0%	1,792/14,991	9.8%	241/2,453	12.2%	235/1,923	12.4%	1,316/10,615

The second set of regression results in Table 3 shows marginal effects from an IV probit model, fit in a single step using maximum likelihood, with standard errors clustered at the clinic level. The instrument is a dichotomous variable equal to 1 if the patient received surgery at a hospital that offers radiation therapy. The coefficient on the instrument from a "first stage" linear probability model that assess the impact of the instrument and the other independent variables on the likelihood of receiving radiation therapy in a freestanding clinic is -0.38 (i.e., 38 percentage points) and is significant at the 1% level. Results from the IV probit model are similar to those from the baseline model. The F-statistic associated with the instrument is 152.

The third set of regression results are from an IV probit model estimated on the subsample of patients who received surgery at a hospital. Marginal effects are similar to those from the other models.

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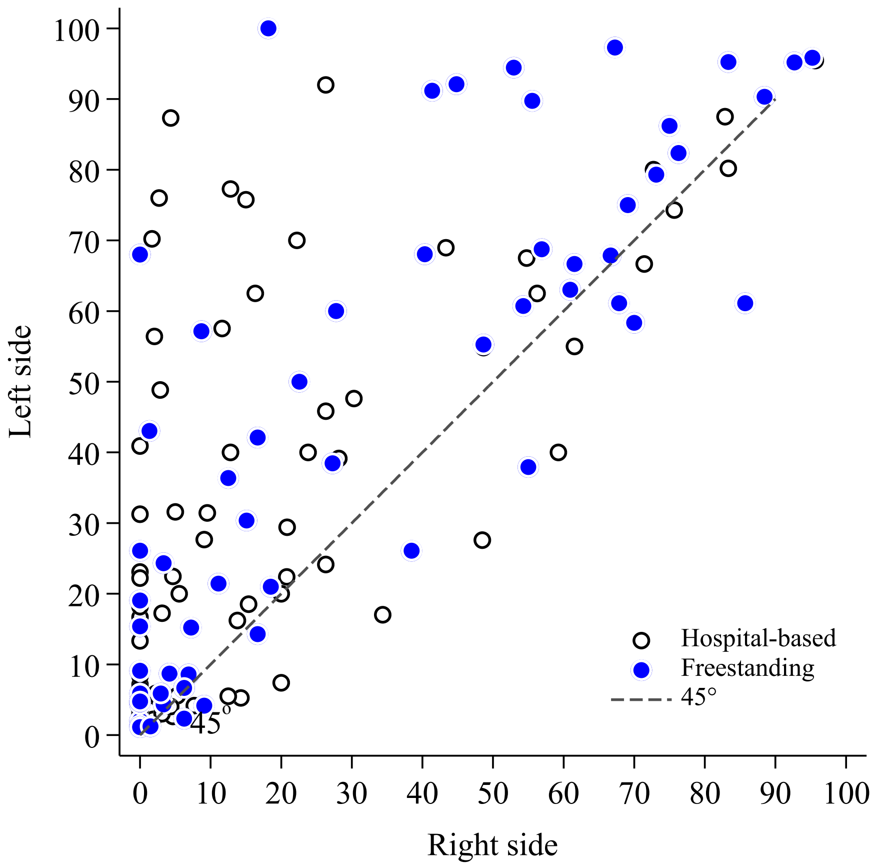
Figure 5 shows clinic-level treatment patterns for clinics that treated at least 30 patients between 2008 and 2013. Circles above the 45 degree line indicate clinics where the share of patients with left-side tumors who receive IMRT exceeds the share of patients with right-side tumors who receive IMRT. There is substantial heterogeneity in clinic treatment patterns. Freestanding clinics seem to be disproportionally represented among clinics that have IMRT use rates above 50% and cluster around the 45 degree line.

Figure 5: Radiology group-level IMRT rates



The sample includes radiology groups that treated at least 30 breast cancer patients over the study period and used IMRT in at least one.

Table 6 shows unadjusted rates and differences in the use of IMRT by clinic type and tumor laterality. Interestingly, patients with right-sided tumors in freestanding clinics are more likely to receive IMRT than patients with left-sided tumors treated in hospital based clinics.

The difference in IMRT use between patients with left- and right-side tumors is 2.1 percentage points higher in freestanding clinics. The adjusted difference, from a logistic model that includes an interaction between clinic type and tumor laterality, is 2.2 (-2.0 to 6.2) percentage points. The confidence interval is wide, but the direction is consistent with the prediction that treatment rates among high-benefit patients are more responsive to incentives.

Table 6: Differences in the use of IMRT by clinic type and tumor laterality

	Radiotherapy clinic type					
	Freestanding		Hospital		Difference	
			%			
Right	26.1	(24.8, 27.5)	8.5	(7.8, 9.1)	17.6	(16.2, 19.1)
Left	35.1	(33.6, 36.5)	15.3	(14.5, 16.1)	19.7	(18.1, 21.4)
Difference	8.9	(7.0, 10.9)	6.9	(5.8, 7.9)	2.1	(-0.2, 4.3)

Conclusions

Personalized medicine has the potential to help physicians better match patients to treatments and reduce costs in the process. However, effects of new tests and algorithms will depend on the financial incentives facing physicians. When physicians face incentives to induce demand, additional information may lead to higher levels of treatment.

Tumor laterality is not a diagnostic test, but, like many highly-touted personalized medicine tests, it groups patients based on their ability to benefit from a treatment. Because it is readily observable, we can study how laterality affects treatment decisions without having to worry about physicians' up-front decision to obtain the information in the first place.

Consistent with prior studies, we find that patients treated in freestanding clinics are substantially more likely to receive IMRT, suggesting that treatment decisions are being influenced by physicians' ability to profit from IMRT. We also find that while women with right-side tumors are less likely to receive IMRT compared to women with left-side tumors in freestanding clinics, they still receive IMRT at much higher rates than women with left-side tumors treated in hospital-based clinics. These results highlight the challenge of maximizing the benefit of tests that imperfectly predict patients' ability to benefit from a treatment in an environment where physicians' compensation is tied to the volume of treatments they provide.

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