Rapid Increase in Breast Magnetic Resonance Imaging Use Trends From 2000 to 2011

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IMPORTANCE Breast magnetic resonance imaging (MRI) is highly sensitive for detecting breast cancer. Low specificity, cost, and little evidence regarding mortality benefits, however, limit recommendations for its use to high-risk women. How breast MRI is actually used in community settings is unknown.

OBJECTIVE To describe breast MRI trends and indications in a community setting.

DESIGN, SETTING, AND PARTICIPANTS Retrospective cohort study at a not-for-profit health plan and multispecialty group medical practice in New England of 10,518 women aged 20 years and older enrolled in the health plan for at least 1 year who had at least 1 breast MRI between January 1, 2000, and December 31, 2011.

MAIN OUTCOMES AND MEASURES Breast MRI counts were obtained from claims data. Clinical indication (screening, diagnostic evaluation, staging or treatment, or surveillance) was determined using a prediction model developed from electronic medical records on a subset of participants. Breast cancer risk status was assessed using claims data and, for the subset, also through electronic medical record review.

RESULTS Breast MRI use increased more than 20-fold from 6.5 per 10,000 women in 2000 to 130.7 per 10,000 in 2009. Use then declined and stabilized to 104.8 per 10,000 by 2011. Screening and surveillance, rare indications in 2000, together accounted for 57.6% of MRI use by 2011; 30.1% had a claims-documented personal history and 51.7% a family history of breast cancer, whereas 3.5% of women had a documented genetic mutation. In the subset of women with electronic medical records who received screening or surveillance MRIs, only 21.0% had evidence of meeting American Cancer Society (ACS) criteria for breast MRI. Conversely, only 48.4% of women with documented deleterious genetic mutations received breast MRI screening.

CONCLUSIONS AND RELEVANCE Breast MRI use increased steeply over 10 years and then stabilized, especially for screening and surveillance among women with family or personal history of breast cancer; most women receiving screening and surveillance breast MRIs lacked documented evidence of meeting ACS criteria, and many women with mutations were not screened. Efforts are needed to ensure that breast MRI use and documentation are focused on those women who will benefit most.

Published online November 18, 2013.
Breast magnetic resonance imaging (MRI) was introduced into clinical practice in the 1990s. Multiple studies have shown that MRI is more sensitive than mammography in detecting breast cancer but has lower specificity and substantially higher cost and is more invasive, requiring an intravenous injection of contrast material. Furthermore, there have been no randomized trials to determine whether the use of breast MRI decreases breast cancer mortality more than the use of mammography. Because of breast MRI’s limitations, cost, and lack of evidence on patient outcomes, most expert groups have recommended limiting its use to patients at substantially increased risk of breast cancer, such as women who have deleterious genetic mutations or strong family histories of breast cancer, or for selected clinical situations. Health benefits may not outweigh potential harms for women at lower risk of breast cancer.

Little is known about how breast MRI is used in community practice. In the early 2000s, the availability of breast MRI services was limited and use was rare. By 2007, nearly 75% of a national sample of breast imaging facilities offered breast MRI. In our setting, we found a total of 333 documented breast MRIs in a population of more than 80,000 women from 2000 through 2004, with half performed for diagnostic purposes. In a study of Medicare-insured women with breast cancer, use increased from 3% in 2003 to 10% in 2005, although the indication was not specified. According to the 2010 US National Health Interview Survey, approximately 2% of US women surveyed (253 of 11,222) self-reported having a recent breast MRI, with the majority (60%) reporting having diagnostic MRI. A study in a community hospital found that half of the breast MRIs performed between 2007 and 2009 were for screening or surveillance. Long-term trends in rates of MRI use overall and by indication are largely unknown.

We examined the trend in breast MRI use over the past decade in a large not-for-profit health plan covering several states in New England. We also estimated trends in breast MRI use for specific indications—screening, diagnosis, staging or treatment, and surveillance—by applying a prediction model for breast MRI indication developed using clinical notes from a subset of women. For that subset of women, we also examined appropriate use based on the 2007 American Cancer Society (ACS) guidelines among women undergoing screening or surveillance breast MRIs.

Methods

Study Settings
Data for this study were drawn from 2 settings: Harvard Pilgrim Health Care (HPHC) and Atrius Health. Harvard Pilgrim Health Care is a large not-for-profit health plan covering more than 1 million members in Massachusetts, New Hampshire, and Maine. Atrius Health is a large nonprofit consortium of multispecialty medical groups in Massachusetts, serving more than 700,000 patients, that share a common electronic medical record system. Approximately 30% of Atrius Health patients were insured by HPHC during the study period. This study was approved by the institutional review board at Harvard Pilgrim Health Care Institute.

Overall Breast MRI Use
We used automated medical claims data from HPHC to document overall trends in breast MRI use during the study period. We identified women aged 20 years and older who had at least 1 breast MRI performed from January 1, 2000, to December 31, 2011. Bilateral and unilateral breast MRI procedures were identified through Current Procedural Terminology codes (76093 or 76094 prior to December 31, 2006; 77058 or 77059 after January 1, 2007) and Healthcare Common Procedure Coding System codes (C8903 through C8908). We restricted analysis to women continuously enrolled in HPHC for at least 6 months before and after each MRI procedure.

Breast MRI Use by Clinical Indication
Breast MRI procedure codes in medical claims are not specific to clinical indication. Therefore, to examine trends by clinical indication in the HPHC population, we developed a model to predict clinical indication. To develop the model, we used electronic medical record data and free-text provider notes from the subset of HPHC members who underwent at least 1 breast MRI between January 1, 2000, and December 31, 2008, and for whom both HPHC medical claims and Atrius Health electronic medical records for the breast MRI were available (the HPHC-Atrius Health subset). We determined the clinical indication for each MRI in this subset on the basis of the following definitions:

1. Screening. If performed on a woman with no prior diagnosis of invasive or in situ breast cancer who was asymptomatic at the time of the MRI and who had no physical or breast imaging abnormalities in the prior 6 months;
2. Diagnostic. If performed as part of the diagnostic evaluation or follow-up of a breast symptom or physical abnormality noted by the woman or her clinician and/or a radiologic breast abnormality, including 1 noted on a prior breast MRI, in the prior 6 months;
3. Staging or treatment. If performed on a woman who had a new biopsy-proven diagnosis of breast cancer in the prior 6 months, to examine extent of breast cancer, inform definitive treatment choice, or monitor neoadjuvant treatment response; and
4. Surveillance for recurrence. A routine breast MRI performed on a woman with a prior diagnosis of invasive or in situ breast cancer, with no new symptoms or findings and more than 6 months after definitive surgery or treatment. The few MRIs performed for the sole purpose of evaluating a symptom or sign related to a breast implant (eg, suspected rupture) were categorized separately.

Two of us (N.K.S., E.S.M.) assessed the clinical indication for each MRI in the HPHC-Atrius Health subset. Disagreements were reconciled by means of independent review by one of us (S.W.F., L.N.). The abstracted clinical indication for each breast MRI was then linked to the corresponding HPHC claim.

Prediction Model for Clinical Indication
With the linked abstracted indication and HPHC claims data from the HPHC-Atrius Health subset, we used multinomial lo-
Atrius Health subset, reserving the remaining half for validation. We built the model using a random sample of half of the HPHC–Atrius Health subset, with the remaining half used for validation. We used logistic regression analysis to develop a model that predicted the clinical indication from diagnostic and procedure codes in the medical claims. The model also included information about the timing of these diagnoses and procedures relative to each breast MRI (eTable in Supplement). Predictor variables remained in the final model were chosen on the basis of their relevance to the clinical indication definitions, as well as their added contribution to the overall log likelihood of the model. We built the model using a random sample of half of the HPHC–Atrius Health subset, reserving the remaining half for validation and calculating sensitivity and positive predictive value, overall and for each clinical indication.

**Analysis**

Women’s characteristics, including age and breast cancer risk, were determined using HPHC enrollment data and diagnosis codes available in the medical claims. For the women who underwent screening or surveillance MRIs in the HPHC–Atrius Health subset, we also determined breast cancer risk by means of review of the clinical notes in the electronic medical records to assess whether the ACS guideline criteria were met.

We calculated overall and indication-specific breast MRI use rates per 10 000 women in the HPHC population for calendar years 2000 through 2011. Indication-specific breast MRI use was estimated by applying the prediction model to the HPHC claims data. To avoid overcounting prior to the introduction of breast-specific MRI machines that allowed a bilateral MRI to be performed as a single procedure, 2 MRIs within 10 days of each other before 2006 were assumed to be equivalent to 1 bilateral MRI. For each year, the denominator comprised all women aged 20 years and older enrolled in HPHC, adjusted to reflect the eligibility requirements of 1 year of continuous enrollment in the numerator.

Annual percent changes in overall and indication-specific rates were estimated using the Joinpoint Regression Program software, version 3.5.4. Joinpoint fits line segments to the data and determines statistically significant differences in slope between 2 connected line segments that indicate points of change in trend. 20 All other analyses, including the development of the prediction model, were conducted in Stata software, version 10 (StataCorp).

### Results

**Patient Characteristics**

The mean annual HPHC-insured population of women aged 20 years and older was more than 250 000 during the study period. We identified 13 339 women with 1 or more breast MRIs, who altogether had 23 276 breast MRIs. Applying the eligibility criteria excluded 2821 women who did not meet the 6-month enrollment window before and after the breast MRI, leaving 10 518 women aged 20 years and older who had a total of 18 215 breast MRIs for our analysis (Table 1). These women were comparable in demographic characteristics to those who did not meet the eligibility requirements (data not shown). The women ranged in age from 20 to 89 years, and the mean age at first MRI was 49.5 years; 65% had only 1 MRI during the study period. We identified 10 518 women aged 20 years and older who had a total of 23 276 breast MRIs. Applying the eligibility criteria excluded 2821 women who did not meet the 6-month enrollment window before and after the breast MRI, leaving 10 518 women aged 20 years and older who had a total of 18 215 breast MRIs for our analysis (Table 1).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>HPHC Cohort</th>
<th>Subset of HPHC Cohort Who Received Care at Atrius Health</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥1 MRI, Women, No.</td>
<td>10 518</td>
<td>998</td>
</tr>
<tr>
<td>MRIs, No.</td>
<td>18 215</td>
<td>1636</td>
</tr>
<tr>
<td>Age at first MRI, y, Women, No. (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20–29</td>
<td>187 (1.8)</td>
<td>16 (1.6)</td>
</tr>
<tr>
<td>30–39</td>
<td>1247 (11.9)</td>
<td>91 (9.2)</td>
</tr>
<tr>
<td>40–49</td>
<td>3891 (37.0)</td>
<td>338 (33.8)</td>
</tr>
<tr>
<td>50–59</td>
<td>3660 (34.8)</td>
<td>387 (38.8)</td>
</tr>
<tr>
<td>60–69</td>
<td>1356 (12.9)</td>
<td>136 (12.6)</td>
</tr>
<tr>
<td>70–79</td>
<td>157 (1.5)</td>
<td>26 (2.6)</td>
</tr>
<tr>
<td>≥80</td>
<td>20 (0.2)</td>
<td>4 (0.4)</td>
</tr>
<tr>
<td>MRIs per woman, mean (range)</td>
<td>1.73 (1-12)</td>
<td>1.64 (1-9)</td>
</tr>
<tr>
<td>Multiple MRIs, Women, No. (%)</td>
<td>3709 (35.3)</td>
<td>338 (32.9)</td>
</tr>
<tr>
<td>Breast cancer risk category, Women, No. (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal history of breast cancer</td>
<td>3167 (30.1)</td>
<td>275 (27.6)</td>
</tr>
<tr>
<td>Genetic mutation</td>
<td>372 (3.5)</td>
<td>28 (2.8)</td>
</tr>
<tr>
<td>Family history of breast cancer</td>
<td>5439 (51.7)</td>
<td>422 (42.3)</td>
</tr>
</tbody>
</table>

* HPHC cohort is restricted to individuals who were continuously enrolled in HPHC during the 6-month period before and after a breast MRI. If a woman had multiple MRIs, only those MRIs that met the enrollment criteria were included.

1 The subset of HPHC-insured patients receiving care at Atrius Health during 2000-2008 (restricted to those meeting 6-month eligibility criteria) with medical record-abstracted clinical indications for each breast MRI.

2 Risk categories defined by presence of diagnostic or procedure code in HPHC claims data at least 45 days prior to the breast MRI for personal history of breast cancer and in the year prior or subsequent to breast MRI for the remaining categories. Categories are not mutually exclusive. Personal history of breast cancer defined by presence of at least 1 International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) code 174, 233.0, V10.3; deleterious genetic mutation for breast cancer defined by ICD-9-CM code V84.01; and family history of breast cancer defined by ICD-9-CM code V16.3.

3 HPHC claims data. To avoid overcounting prior to the introduction of breast-specific MRI machines that allowed a bilateral MRI to be performed as a single procedure, 2 MRIs within 10 days of each other before 2006 were assumed to be equivalent to 1 bilateral MRI. For each year, the denominator comprised all women aged 20 years and older enrolled in HPHC, adjusted to reflect the eligibility requirements of 1 year of continuous enrollment in the numerator.

### Overall Breast MRI Use

Breast MRI use increased approximately 16-fold from 198 (6.5 per 10 000 women) in 2000 to 2744 (104.8 per 10 000) by 2011. From 2003 through 2011, the average annual percentage increase was 21% (Table 2). However, a statistically significant change in trend occurred in 2008; between 2003 and 2008, use increased annually by 46% (95% CI, 39%-52%), and then it decreased annually by 10% (95% CI, −19% to −1%) from 2009 through 2011. Age-specific rates followed similar time trends; rates increased over time across all ages through 2009 and showed subsequent declines (Figure A). Women in their 40s and 50s consistently had the highest rates of use.
Estimation and Validation of Prediction Model for Clinical Indication

We documented clinical indications for 2072 MRIs from the subset of 1169 HPHC-insured women cared for at Atrius Health who received at least 1 breast MRI from 2000 through 2008 (225 of whom were included in an earlier study). We were unable to determine indication for 175 breast MRIs. Enrollment eligibility requirements reduced the sample to 1636 breast MRIs from 998 women; 758 were used for model development and 878 for validation. Magnetic resonance images related to breast implants (36 of 1636) were included in the overall model estimation; however, we excluded them from the indication-specific analysis because we were interested in applications associated with breast cancer.

The final prediction model contained 15 variables (eTable in Supplement) describing the timing of breast imaging, diagnostic and treatment procedures, prior breast MRIs, family and genetic risk for breast cancer, benign breast disease, and breast cancer diagnoses. The model had an overall prediction accuracy of 92% in the validation set, and positive predictive values in the validation set ranged from 76% to 88% for the 4 clinical indications. The prediction model misclassified approximately 16% of the breast MRIs performed for screening and surveillance as diagnostic, primarily because of the timing of a prior abnormal mammogram that required additional breast imaging other than MRI to resolve.

Breast MRI Use by Clinical Indication

Similar to the trends in overall use, we found that rates for all 4 indications increased over time and peaked between 2008 and 2009 and then declined or stabilized (Figure, B). The greatest increase was in use of breast MRI for screening and surveillance. From 2003 through 2008, use for screening and surveillance increased an average of 76% and 61%, respectively, per year (Table 2). Diagnostic breast MRI comprised 59% of all breast MRIs in 2003 but only 28% in 2011. By 2011, screening was the leading breast MRI indication, at 32.3 per 10,000 women (31% of total use); use for diagnosis and surveillance followed at 29.8 and 28.1 per 10,000, respectively.

Only 3.5% of women had a deleterious genetic mutation for breast cancer noted in medical claims (Table 4). Women undergoing screening and surveillance MRI had a higher frequency of this marker compared with those undergoing MRI for the other indications (5.1%-5.9% vs 2.0%-3.1%). Nearly half of the women with a mutation noted (180 of 372) underwent MRI for screening. Whereas 82.0% of women undergoing screening MRIs had a family history of breast cancer noted in their medical claims, this was true for only approximately 40% of those undergoing MRI for other indications. Among women in the HPHC–Atrius Health subgroup who underwent at least 1 screening or surveillance breast MRI, we found that 21.0% (90 of 429) had family history documentation and/or positive mutation status in their medical records supporting a lifetime risk greater than 20%.

More women undergoing breast MRI for screening or surveillance purposes had multiple MRIs (27.7% and 44.5%, respectively) compared with those undergoing MRI for diagnostic or staging or treatment purposes (21.0% and 19.1%, respectively) (Table 4). Furthermore, whereas only 11% of all women had 3 or more breast MRIs for the same clinical indication, more than 70% were women undergoing screening or surveillance MRI. Women undergoing MRI for screening purposes were typically younger than women receiving MRI for other reasons.

Discussion

Breast MRI use increased more than 20-fold, from 6 to 131 per 10,000 women, between 2000 and 2009 and then declined slightly to 105 per 10,000 by 2011 in a large multisite health plan in New England. Rates of breast MRI use by age followed the same trends, with the highest use among women aged 40 to 59 years. From 2000 through 2009, breast MRI use increased for all indications-screening, diagnostic workup, staging or treatment, or surveillance for recurrence—with use for screening and surveillance showing the greatest increases. After 2009, use declined for diagnostic workup and stabilized for the other indications. Although rare early in the decade, screening and surveillance together accounted for nearly 60% of all breast MRIs by 2011. To our knowledge, this is the first study to document trends in breast MRI rates over more than a decade in a large community-based population with commercial insurance.
In 2007, the ACS released guidelines recommending routine use of breast MRI as an adjunct screening tool for women with at least a 20% lifetime risk of breast cancer due to genetic mutations and/or a strong family history of breast cancer. In our study, screening was the fastest growing indication for a breast MRI, but only approximately half of the 372 women with a claims-documented history of genetic mutations had screening breast MRI and of those, half had multiple screening MRIs. This pattern suggests that recommendations for screening high-risk women with breast MRI are beginning to be followed in community practice, but the fact that only half of those eligible for screening breast MRI had one suggests that more should be done. Also, according to several estimates, as many as 6% of all women may be eligible for screening MRI. Of approximately 250,000 women, only 3049 (1.2%) underwent screening MRI in our study and of those, few (180 women) had a claims-documented history of a genetic mutation. Most women undergoing screening breast MRI (approximately 80%) had a family history of breast cancer noted in their medical claims. Because claims lack detailed information about...
family history, it is unclear whether use of screening breast MRI is appropriate for all of these women; on the basis of our review of medical records for the HPHC-Atrius Health subgroup, we found that only 21% undergoing screening or surveillance MRI had evidence to meet the ACS criteria, partly because family history was rarely detailed. Breast MRI has a high false-positive rate, and broadening the scope of use to women with lower risk would decrease the positive predictive value of the test. Implications of this “indication creep” include increased downstream resource use and cost, as well as potential harm to women through the cascade of additional imaging and invasive procedures for diagnostic resolution.

Surveillance was the second fastest growing indication for breast MRI. Patterns of use were similar to those for screening, yet surveillance breast MRI is generally recommended only for women who have a genetic mutation and/or strong family history and is not recommended for most women who have a personal history of breast cancer. We found that 4% of women receiving breast MRIs for surveillance had genetic mutations and 43% had a family history of breast cancer noted in claims.

Breast MRI was originally used for diagnostic evaluation in the decision regarding whether to biopsy a suspicious lesion and for treatment to assess disease extent or monitor response to neoadjuvant therapy. Use of MRI for these indications is not routinely recommended, in part because of mixed evidence about benefits and concerns about invasive processes. The declining use of breast MRI for these indications that we estimated in recent years may reflect increasing consensus about the limited benefit.

We found that overall use increased on average 46% per year through 2009 and began to decrease and stabilize thereafter. These trends are consistent with predictions about the diffusion of new technology. The stabilization of rates after 2009 is also consistent with trends in the use of noninvasive diagnostic imaging in general, although our observed increase in breast magnetic resonance imaging use.

Table 3. Discrimination Ability of the Clinical Indication Prediction Model to Predict the 4 Breast Cancer-Specific Clinical Indications for Breast Magnetic Resonance Imaging in the Validation Data Set From the Harvard Pilgrim Health Care-Atrius Health Subset

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Abstructed Indication</th>
<th>Screening</th>
<th>Diagnostic</th>
<th>Staging or Treatment</th>
<th>Surveillance</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model-predicted indication, No.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Screening</td>
<td></td>
<td>131</td>
<td>21</td>
<td>1</td>
<td>0</td>
<td>153</td>
</tr>
<tr>
<td>Diagnostic</td>
<td></td>
<td>26</td>
<td>263</td>
<td>17</td>
<td>38</td>
<td>344</td>
</tr>
<tr>
<td>Staging or treatment</td>
<td></td>
<td>0</td>
<td>15</td>
<td>111</td>
<td>10</td>
<td>136</td>
</tr>
<tr>
<td>Surveillance</td>
<td></td>
<td>1</td>
<td>17</td>
<td>8</td>
<td>188</td>
<td>214</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>158</td>
<td>316</td>
<td>137</td>
<td>236</td>
<td>847</td>
</tr>
</tbody>
</table>

Prediction accuracy, %
- Sensitivity: 83 83 81 80
- PPV: 86 76 82 88
- Total: 82

Table 4. Women’s Use of Breast Magnetic Resonance Imaging (MRI) by Breast Cancer Risk and Number

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>All Women, No. (%) (N = 10,518)</th>
<th>Clinical Indication, Women, No. (%)</th>
<th>Screening (n = 5330)</th>
<th>Diagnostic (n = 3049)</th>
<th>Staging or Treatment (n = 2113)</th>
<th>Surveillance (n = 2116)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breast cancer risk category</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal history</td>
<td>3167 (30.1)</td>
<td>0</td>
<td>1077 (20.2)</td>
<td>2113 (100)</td>
<td>2086 (98.6)</td>
<td></td>
</tr>
<tr>
<td>Genetic mutation</td>
<td>372 (3.5)</td>
<td>180 (5.9)</td>
<td>107 (2.0)</td>
<td>66 (3.1)</td>
<td>108 (5.1)</td>
<td></td>
</tr>
<tr>
<td>Family history</td>
<td>5439 (51.7)</td>
<td>2501 (82.0)</td>
<td>2283 (42.8)</td>
<td>863 (40.8)</td>
<td>905 (42.8)</td>
<td></td>
</tr>
<tr>
<td>Breast MRIs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>6810 (64.7)</td>
<td>1687 (55.3)</td>
<td>3204 (60.1)</td>
<td>1143 (54.1)</td>
<td>688 (32.5)</td>
<td></td>
</tr>
<tr>
<td>&gt;1</td>
<td>3708 (35.3)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>&gt;1 for same indication</td>
<td>2937 (27.9)</td>
<td>846 (27.7)</td>
<td>1120 (21.0)</td>
<td>403 (19.1)</td>
<td>941 (44.5)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviation: NA, not applicable.
- Sum across clinical indications is greater than total because women may have undergone multiple MRIs, each with a different clinical indication.
- Risk categories defined by presence of diagnostic or procedure code in Harvard Pilgrim Health Care claims data at least 45 days prior to the breast MRI for personal history of breast cancer and in the year prior or subsequent to breast MRI for the remaining risk category. For staging or treatment breast MRI, no restriction on timing was used in defining personal history of breast cancer. Categories are not mutually exclusive.
- Categories are not mutually exclusive.

Abbreviation: PPV, positive predictive value. a Sensitivity equals number correctly predicted by the model divided by the total number of MRIs assigned after medical record abstraction, for each indication. b PPV equals number of MRIs correctly predicted by the model divided by the total number assigned after medical record abstraction, for each indication.
annual increases in breast MRI use prior to 2009 were much larger than those for all MRI regardless of body site.\textsuperscript{33,34} For example, in settings similar to ours, use of MRI overall increased between 11% and 26% annually early in the decade and then slowed to 6.5%.\textsuperscript{33,35,36}

Our study was conducted in a large health plan that spans multiple states. Nevertheless, community practice in New England may not be generalizable to other regions in the United States. High regional variation in the use of diagnostic imaging has been reported in the Medicare population, although use in the New England region was similar to the national mean.\textsuperscript{37} Our findings also may not be generalizable to practices with different availability of the technology and/or policies of the insurer. The coverage policies of HPHC, as of 2011, allowed use of breast MRI for all of the indications studied. Populations of women with other forms of insurance may have experienced different rates and trends in use.

Our indication-specific rates from 2000 through 2011 in the HPHC population were based on a classification of procedures derived from a multinomial logistic prediction model. This model was based on information abstracted from physician notes regarding the purpose of the MRI in combination with medical claims data. The model showed reasonable prediction accuracy of more than 80% and positive predictive values of 76% to 88%, although some screening and surveillance MRIs were misclassified as diagnostic. The rates of screening and surveillance breast MRIs that we report may underestimate actual use. Because our prediction model was constructed and validated using data through 2008, trends in use during the period after 2008 are an extrapolation. Finally, in our HPHC-Atrius Health subset, we found that information about genetic markers in claims corresponded with documentation in medical records only approximately half of the time and was underreported in claims compared with medical records. Therefore, our estimate that less than 1% of women undergoing MRI had a genetic mutation is low. However, the percentage of women with any evidence of genetic mutations was so low (4%) that it is clear that such evidence was rare in our study population. Overall, we found evidence that women met ACS guidelines for screening MRI in only 21% of those undergoing screening or surveillance MRI.

Breast MRI use has expanded rapidly over the past decade. We found that increases occurred for all indications but especially screening and surveillance. Use has stabilized and begun to decline since 2009. Although benefits for some indications have been inferred from observational and modeling studies,\textsuperscript{10,38-40} the increases in use have occurred without strong evidence of long-term mortality benefits. The overall impact on health outcomes and medical care costs from breast MRI use in the community remains unknown. As with most medical technologies, indication creep is likely inevitable.\textsuperscript{41,42} Our data suggest that the majority of women who underwent screening breast MRI did not meet the recommended criteria for appropriate use, whereas many who did meet the criteria did not undergo screening breast MRI. However, to clearly understand appropriateness of use, better documentation of breast cancer risk is needed. Understanding who is receiving breast MRI and the downstream consequences of this use should be a high research priority to ensure that the limited health care funds available are used wisely to maximize population health.
Increase in Breast Magnetic Resonance Imaging Use

Original Investigation Research

older patients with newly diagnosed breast cancer.


