CURRENT ONCOLOGY
A Canadian Cancer Research Journal

ORIGINAL ARTICLE

Breast magnetic resonance imaging: are those who need it getting it?

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ABSTRACT

Background Indications for breast magnetic resonance imaging (MRI), a very sensitive but less-specific tool for breast investigation, remain controversial, and accessibility is limited. The purposes of our study were to determine the proportion of breast MRI exams performed for various clinical indications, to assess the wait times for breast MRI, and to create a list of evidence-based indications for breast MRI.

Methods The indications for breast MRI exams performed in September 2013 at our academic centre were audited. A multidisciplinary meeting held in May 2014 established a list of evidence-based indications for breast MRI, after which, in September 2014 and 2015, breast MRI exams were re-audited for clinical indications, and pending requests were calculated.

Results In September 2013, surveillance of women with a prior diagnosis of breast cancer represented 21% of breast MRI exams (24 of 113), with preoperative staging representing 18% of exams (20 of 113) and high-risk screening representing 12% (13 of 113). Of pending MRI requests, 230 were within the recommended delay period, and 457 exceeded the recommended delay. After elaboration of evidence-based guidelines, repeat audits in September 2014 and September 2015 showed that MRI performed for women with a prior breast cancer diagnosis represented 23% (33 of 141) and 7% (10 of 143) of exams respectively, with preoperative staging having declined to 9% (13 of 141) and 11% (16 of 143) of exams, and high-risk screening having increased to 36% (51 of 141) and 46% (66 of 143) of exams. Overall, wait times were improved for all breast MRI indications.

Conclusions Through multidisciplinary discussion, we actualized a list of breast MRI indications, prioritized requests more adequately, and improved wait times.

Key Words Breast cancer, imaging, MRI

Curr Oncol. 2017 June;24(3):e205-e213 www.current-oncology.com

BACKGROUND

The Canada Health Act governs every health system in Canada and ensures universal access to health care for all Canadian residents. However, accessibility, another principle of the Canada Health Act, can become compromised. Lately, the federal government and the Wait Time Alliance have been particularly concerned about accessibility to cancer care and diagnostic imaging[1,2]. In the 2015 Wait Time Alliance report[3], wait times for magnetic resonance imaging (MRI) were on the rise in Ontario and Manitoba and exceeded recommended benchmarks for more than 50% of the population in Alberta and Prince Edward Island. (Data for the other 6 provinces are unknown because sufficient data for the assessment were not provided.)

Despite the limited availability of MRI, indications for MRI exams are increasing exponentially. In breast imaging, MRI is indicated for the detection and management of breast cancer, offering a sensitivity for cancer detection superior to that with other imaging modalities—ranging between 71% and 100%[4–11]. Between 2000 and 2009, demand for breast MRI soared, increasing by a factor of more than 20[12]. However, breast MRI must be used with discernment given its limited specificity: very low in the earliest reports, but now generally accepted to be in the 60%–80% range[4–11]. Moreover, evidence is increasing that preoperative staging MRI might be detrimental to patients, unnecessarily lengthening their investigation time because of the detection of additional nonspecific findings[13,14] and increasing the mastectomy rate with little reduction in re-excision

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and negative margins rates[15]. In that context, there has been a call for moderation with respect to routine orders for staging breast MRI because no randomized controlled trial has yet demonstrated improved survival for women who undergo breast MRI[16].

Although several publications have analyzed breast MRI and its use, application of the resulting knowledge does not necessarily translate in day-to-day practice. In 2014, the Breast Cancer Surveillance Consortium reported that only 25% of screening MRI exams were performed for appropriate indications as defined by the American Cancer Society guidelines[17]. Conversely, fewer than 5% of patients at high risk of breast cancer received breast MRI[17]. In this era in which wait lists for MRI exams and health costs are constantly growing, improved patient selection is urgently needed[18].

In the fall of 2013, given the increasing controversy about the use of breast MRI, particularly as a preoperative staging tool, and given the lengthy wait lists for breast MRI at our institution, we audited our breast MRI use. Using a problem-solving model to bridge the gap between academic knowledge and clinical practice, we strove to improve quality of care by a method that could be applied at other institutions as well. The objectives of our project were to

- determine how breast MRI was being used at our academic centre, and particularly the proportions of breast MRI exams performed for various clinical indications;
- assess the wait times for breast MRI;
- review the literature about breast MRI indications with our multidisciplinary panel of breast specialists; and
- create a list of evidence-based indications for breast MRI.

METHODS

The study used a clinical audit strategy model.

Identify the Problem

The study was performed at the Centre hospitalier de l'Université de Montréal, an academic tertiary-care hospital where the medical team includes 5 fellowship-trained breast imagers and 5 onco-surgeons specializing in breast surgery. Our breast clinic is an investigation site (Centre de référence pour investigation désigné) for the Quebec Breast Cancer Screening Program, and it receives referrals from other institutions in the province of Quebec, mostly in the wider Montreal area. Annually, about 1600 breast MRI exams are performed.

To evaluate the situation at our institution and to determine the improvements required, all breast MRI exams performed in September 2013 were retrospectively audited. All breast MRI exams completed during that 1-month period were retrieved and collected from our picture archiving and communication system, and the indication for each exam was recorded. We then classified indications into these categories: preoperative staging; screening of high-risk women; follow-up of MRI-identified anomalies; investigations for women with a personal history of breast cancer; surveillance of women with a history of lobular carcinoma *in situ*, atypical ductal hyperplasia, or atypical lobular hyperplasia; troubleshooting (after any one or a combination of inconclusive mammography, ultrasonography, or biopsy); investigation of nipple discharge; and "other," including evaluation of breast implants, search for a primary cancer in the presence of malignant adenopathy, and positive margins after breast surgery.

Evaluate Outcomes

In September 2013, 16 hours were dedicated every week for breast MRI exams, allowing for the evaluation of approximately 26 patients having a standard 30-minute diagnostic exam and 2 patients having MRI-guided breast biopsies (90 minutes allotted per procedure). At the end of September 2013, we analyzed pending breast MRI requests as tracked by our administrative system. We classified every request as being within wait times recommended by the Canadian Association of Radiologists[19] and set out in Quebec governmental guidelines (provincial recommendations are for imaging within 90 days after reception of a first request and within 30 days for follow-up examinations); exceeding wait times by less than 6 months; exceeding wait times by 6–12 months; and exceeding wait times by more than 12 months. We also projected the number of days before the next non-urgent breast MRI would be available.

Adapt Knowledge to Local Context

To verify that our use of breast MRI complied with the latest published recommendations and to improve our service to patients, we organized a multidisciplinary half-day scientific session for the breast team, which was held in May 2014. Of 28 possible participants, 21 attended the meeting, representing all invited fields: 5 radiologists, 4 surgical oncologists, 2 medical oncologists, 2 radiation oncologists, 2 geneticists, 3 breast physicians, and 3 radiology residents. An informal review of the literature about MRI use for breast cancer staging, high-risk screening, and other indications was presented. There was then a discussion until multidisciplinary consensus was reached for a scientifically acceptable compromise between published evidence and MRI availability at our institution.

The ordering radiology form for breast MRI was subsequently modified to reflect the actualized accepted indications for MRI, and steps were taken to make the document easily accessible to all clinicians in their daily clinical work.

Monitor Knowledge Use

In September 2014 and September 2015, we re-audited all breast MRI exams performed during the 1-month period and collected data for each exam's indication. We calculated the number of pending breast MRI requests at the end of both months and categorized them in the same manner as before the consensus.

RESULTS

Pre-consensus Evaluation

Our initial institutional review from September 2013 showed that 27% of breast MRI exams (30 of 113) were performed for follow-up of an MRI-identified lesion. Women with a personal history of breast cancer or needing preoperative staging constituted the 2nd and 3rd most common

indications for women to undergo breast MRI (21%, 24 of 113, and 18%, 20 of 113, respectively). Screening of high-risk women came in 4th place and represented only 12% of all breast MRI studies (13 of 113, Table I).

Review of 687 pending breast MRI requests at the end of September 2013 revealed that 67% exceeded recommended wait times, with 294 (43%) exceeding recommended wait times by less than 6 months, 93 (14%) exceeding them by 6–12 months, and 70 (10%) exceeding them by more than 12 months (Table I). Actuarial calculations estimated that the next elective breast MRI slot would be available in 320 days.

Consensus

Review of the September 2013 breakdown of breast MRI examinations according to indications and compilation of the overall wait times for such exams confirmed that improvement was in order.

Discussion by the 21 members of the breast team who participated in the May 2014 multidisciplinary meeting achieved a consensus regarding the use of breast MRI. Evidence-based accepted indications for breast MRI fell into two major categories: preoperative staging in specific clinical situations and high-risk screening (Table II). For the latter category, given that several requests for women with a strong family history of breast cancer were awaiting formal genetic evaluation, screening MRI was also accepted for women fulfilling the high-risk criteria for familial breast cancer based on the (Australian) National Breast and Ovarian Cancer Centre classification[62]. Discussions also covered when to start and stop MRI screening. Table II presents the full list of evidence-based indications for breast MRI applied at the Centre hospitalier de l'Université de Montréal.

Although evidence from the literature formed the base of our institutional guidelines, the reality of our particular practice was taken into consideration during the multidisciplinary meeting. Our genetics experts suggested referring women for a genetic evaluation when they fulfilled any of these criteria: less than 50 years of age with breast cancer; having a first-degree relative diagnosed with breast cancer before the age of 50; having multicentric cancer; and being diagnosed with triple-negative cancer at a young age. However, because the wait time for a genetic consultation can be relatively long, potentially delaying breast MRI screening for patients who might be at high risk, the consensus of the breast team was to allow patients considered high risk according to clinical criteria who were awaiting genetics evaluation to immediately benefit from annual breast MRI evaluation. The high-risk clinical criteria were based on the Australian classification because that classification is easily applicable[62].

The decision to use MRI to evaluate patients with triple-negative breast cancer was another point of discussion during the meeting. Although results from the ALLIANCE A011104/ACRIN 6694 study on the subject are still pending, radiology experts determined they had the capacity to honour requests for this indication given that patients with triple-negative cancer represent only a small proportion of our patient population.

TABLE I Volume of, and wait times for, breast magnetic resonance imaging (MRI) exams before and after consensus implementation

Variable	Month of September in ...		
	2013	2014	2015
Breast MRI exams performed (*n*)	113	141	143
Exams performed (%) for ...			
Preoperative staging	18	9	11
	(*n*=20)	(*n*=13)	(*n*=16)
High-risk screening	12	36	46
	(*n*=13)	(*n*=51)	(*n*=66)
Women with a personal history of breast cancer	21	23	7
	(*n*=24)	(*n*=33)	(*n*=10)
Follow-up of a MRI-identified lesion	27	13	18
	(*n*=30)	(*n*=18)	(*n*=26)
Total pending breast MRI requests [*n* (%)]	687	612	301
Requests within recommended wait time[a]	230 (33)	168 (27)	129 (43)
Requests exceeding wait time			
By <6 months	294 (43)	182 (30)	82 (27)
By 6–12 months	93 (14)	192* (31)	74 (25)
By >12 months	70 (10)	70* (11)	16 (5)
Actuarial estimate of next non-urgent breast MRI availability (days)	320	250	176

[a] Quebec provincial guidelines are for imaging within 90 days of reception of a first request; follow-up examinations should be performed within 30 days.

It was determined that all requests for breast MRI that deviated from the consensus would no longer be routinely accepted at our institution, including specific situations in which, although the literature might show some evidence of benefit, the benefit is not sufficient to warrant routine use of MRI (Table III). For example, women whose family history suggests a moderate risk for breast cancer are not candidates for MRI screening before formal genetic evaluation, nor are women with no risk factor other than a personal history of breast cancer. Similarly, our literature review did not support continued MRI screening for high-risk women who had undergone bilateral mastectomy whether prophylactic or therapeutic, nor did it support continued MRI surveillance of high-risk women after 69 years of age.

The conclusions from our exchanges were summarized in a written document that was circulated to all 28

TABLE II Institutional consensus of evidence-supported, accepted breast magnetic resonance imaging (MRI) indications

1. Preoperative staging[15,20–39]

   Recommend or consider MRI in these situations:

   - Search for primary breast cancer in woman with metastatic axillary lymph nodes
   - Paget's disease of the nipple
   - Infiltrating lobular carcinoma (unless mammography and ultrasonography evaluations were felt to be radiologically satisfactory)
   - Breast cancer in a woman younger than 35 years of age
   - HER2-positive or triple-negative cancers (as part of research protocols)
   - Before neoadjuvant chemotherapy (unless MRI would not affect surgical planning)
   - Locally advanced breast cancer with suspected pectoralis muscle or skin invasion
   - After surgery with positive margins

2. High-risk screening[36,37,38,40–61]

   Recommend annual MRI screening for these women:

   - Having *BRCA* mutation or being a first-degree relative of a family member with *BRCA* mutation
   - Syndromes[44]
     - Having Li-Fraumeni (*TP53*), Cowden (*PTEN*), or Bannayan–Riley–Ruvalcaba, and their first-degree relatives
   - Lifetime risk exceeding 20% as calculated by breast cancer risk-assessment tool
   - Having had radiation to the chest between the ages of 10 and 30 years

   Recommended MRI screening for women with a strong family history who have not yet been evaluated in genetics when they fulfil these high-risk criteria:

   - Mutation identified in the family
   - Having 3 or more first- or second-degree relatives with breast or ovarian cancer (same side of the family)
   - Having 2 or more first- or second-degree relatives with breast or ovarian cancer (same side of the family) *and* at least 1 of the following risk factors: bilateral cancer, diagnosis at less than 40 years of age, male breast cancer, or breast and ovarian cancer in the same person

When screening MRI should begin

- Start at 25–30 years of age for those with a *BRCA1/2* mutation (or who are a first-degree relative)
- Start at 20 years of age for those with Li-Fraumeni (*TP53*) (or who are a first-degree relative)
- Start at 30 years of age for high-risk patients without formal genetic evaluation
- Start at 8 years after the end of treatment for patients with history of mediastinal radiation therapy

When screening MRI should stop

- Annual screening MRI can cease at 69 years of age for all high-risk patients, regardless of breast density
- For women with prophylactic mastectomy (including removal of the nipple–areola complex)
  - Clinical surveillance if no reconstruction
  - In the presence of an autologous graft, mammography every 18–24 months
  - In presence of breast implants: first postoperative evaluation includes mammography; if no residual breast tissue, perform subsequently physical exam only, no imaging follow-up
- For women with therapeutic mastectomy (including removal of the nipple–areola complex)
  - Clinical surveillance if no reconstruction
  - If reconstruction with an autologous graft: annual mammography
  - If reconstruction with breast implants: postoperative mammography to verify presence of residual tissue and yearly mammography thereafter if tissue is present
- For women with preserved nipple–areola: annual mammography

TABLE III Institutional consensus about breast magnetic resonance imaging (MRI) indications no longer accepted at our institution

There is *not enough evidence* to recommend annual surveillance with MRI for women with these risk factors:
■ Prior history of breast cancer
■ Personal history of lobular neoplasia or atypia (lobular carcinoma *in situ,* atypical lobular hyperplasia, atypical ductal hyperplasia)
■ Women with dense breasts
Screening MRI will not be offered to *women at moderate risk* based on family history, before a formal calculation of their lifetime risk
■ These criteria serve as reference to define moderate risk:
■ 1 or 2 first-degree relatives with breast cancer before 50 years of age (same side of the family) and without high-risk factors
■ 2 first- or second-degree relatives with breast or ovarian cancer (same side of the family) without high-risk factors

members of the breast team for final approval (the 21 who had attended the meeting and the few who had not been able to attend). The final document was then sent by e-mail to all physicians involved in breast care at our institution, and a printout of the consensus was made easily accessible to clinicians and radiologists at their clinics and workstations. It was decided that all breast MRI requests received before the consensus meeting would be honoured, without questioning the indication. However, for every new MRI request received after May 2014 that did not meet the new consensus, a letter informing the referring physician of the rejected request was sent together with the summarized recommendations from the consensus meeting. It was clearly stated that the consensus guidelines aimed to standardize our institution's use of breast MRI, but did not replace the physician's clinical judgment. They were therefore invited to contact the radiologist directly to discuss the case in further detail, if desired.

The ordering radiology form for breast MRI was modified to reflect the consensus guidelines (Table IV). Although our initial prescription form included subcategories of preoperative imaging (re-excision for positive margins and search for primary breast cancer), all subcategories were merged under the single category of preoperative staging. To improve access to screening MRI for women with a genetic susceptibility, the ordering form was also modified to subdivide all screening MRI requests into two groups: women with a proven genetic susceptibility to breast cancer, such as carriers of a *BRCA* mutation and their first-degree relatives; and all other women with sufficiently strong risk factors to justify MRI screening, but with no formal genetic evaluation. Specific reference to our consensus document was added to the new ordering form to reaffirm our determination to respect the institutional consensus.

In addition to detailing the indications for breast MRI, our new ordering form also provided guidelines for exam priority: preoperative staging and evaluation of chemotherapy response are first-priority evaluations (P1); follow-up for probably benign lesions (Breast Imaging Reporting and Data System class 3), problem-solving after mammography and ultrasonography, and investigation of nipple discharge are moderate-priority evaluations (P2); and screening of high-risk women with a genetic susceptibility receive the next priority rating (P3). All other screening requests and implant evaluations are last-priority examinations (P4).

TABLE IV Changes made to the initial prescription form after the consensus

Initial prescription form
Indications
■ Breast cancer
■ Breast Imaging Reporting and Data System (BI-RADS) 5 lesion (awaiting confirmation)
■ Recent diagnosis—evaluate extension
■ Previous diagnosis
■ Screening: high-risk for breast cancer
■ Evaluation of chemotherapy response
■ Search for primary cancer
■ Positive margins post-tumourectomy
■ Short-term magnetic resonance imaging follow-up (BI-RADS 3)
■ Problem-solving: mammography or ultrasound anomaly
■ Nipple discharge
■ Breast implants
■ Post-biopsy follow-up
■ Other
Post-consensus form
Indications
■ Preoperative staging (per the May 2014 consensus)
■ Evaluation of chemotherapy response
■ Short-term follow-up (BI-RADS 3 and post–magnetic resonance imaging biopsy)
■ Problem-solving after mammography and ultrasonography
■ Nipple discharge
■ Screening high-risk women (for example, *BRCA* and first-degree relatives)
■ Screening other women at increased risk
■ Breast implant evaluation

Post-consensus Evaluation

After implementation of the consensus guidelines, the proportion of breast MRI exams performed for each indication changed markedly (Table I, Figure 1). One year after applying the new guidelines, at the first re-audit, screening MRI rose from the 4th most common indication to the most common indication. That trend continued in the subsequent year, with the proportion of screening MRI exams reaching 46% of all breast MRI exams in September 2015, compared with 36% 1 year earlier and only 12% in 2013.

Conversely, the proportion of breast MRI exams performed for preoperative staging was cut in half 1 year after the consensus, dropping to 9% (2014) from 18% (2013). In September 2015, the proportion of preoperative breast MRI exams remained relatively stable at 11%.

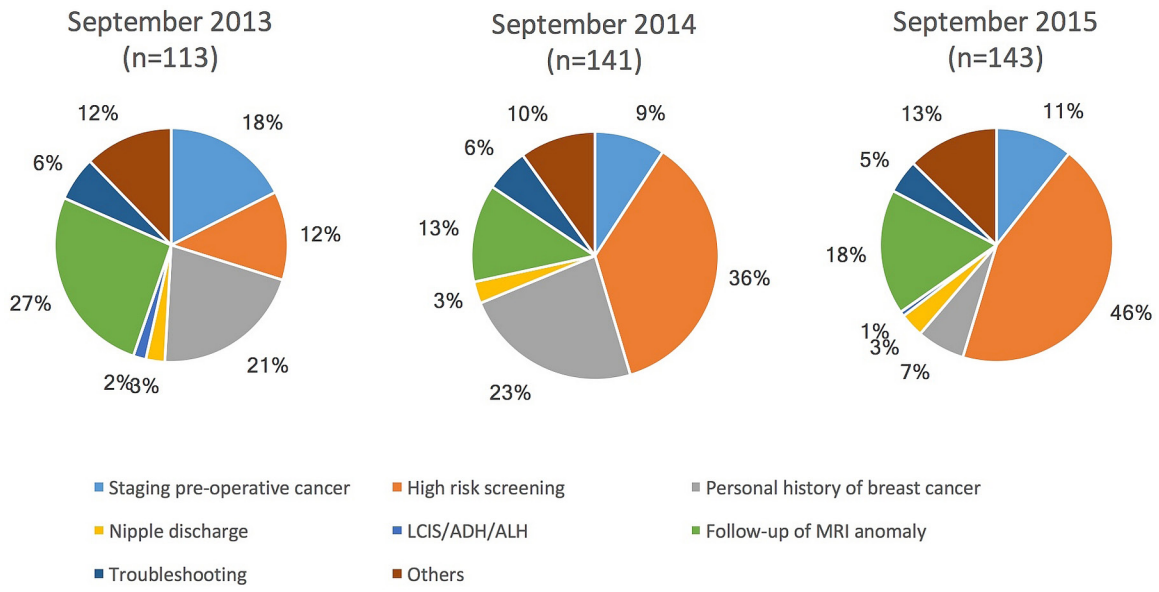

FIGURE 1 The distribution of clinical indications for which breast magnetic resonance imaging (MRI) was performed in the months of September 2013, September 2014, and September 2015. LCIS = lobular carcinoma in situ; ADH = atypical ductal hyperplasia; ALH = atypical lobular hyperplasia.

The 2nd most common indication for breast MRI in 2013 was surveillance of women previously treated for breast cancer, but consensus guidelines established that breast MRI would no longer be performed solely for that risk factor. Because of an important backlog of women awaiting MRI for that indication, the effect of the recommendation was noticed only 2 years after implementation, when the proportion of breast MRI exams for that indication dropped to 7% from the 21% observed in September 2013.

The number of scheduling slots available for breast MRI increased slightly during the study period, to 19 hours from 16 hours weekly, thus allowing 143 breast MRI exams to be performed in September 2015 compared with the 113 performed in September 2013. That measure, combined with an improved selection of women undergoing breast MRI because of clear institutional consensus guidelines having been established, resulted in globally improved wait times for all breast MRI exams (Table I): the 320-day delay for the next available MRI slot in September 2013 was reduced to 176 days in September 2015. Breast MRI requests awaiting scheduling and requests exceeding recommended wait times by less than 6 months also improved in the year after the consensus guidelines were established. Because of the accumulated backlog, the effect of the new guidelines on requests exceeding recommended wait times by more than 6 months was observed only during the 2nd year of follow-up.

DISCUSSION

With the introduction of MRI into the detection and management of breast cancer, multiple associations, including the Canadian Association of Radiologists, the American Cancer Society, and the American College of Radiology, have published guidelines for the appropriate use of breast MRI[38,63,65]. Taking into account more recently published data, those recommendations can be incomplete, contradictory, or outdated for some situations. Moreover, given that policies and distribution of medical resources can be quite different from country to country, recommendations by foreign medical associations should be carefully considered before they are adopted into local practice. The Choosing Wisely Canada campaign—based on the concept that good care for patients is achieved by prescribing the right tests to the right patients[64,65]—is crucial considering the high cost and limited availability of breast MRI. With its excellent sensitivity but lower specificity, MRI leads to additional tests and investigations, increased costs, and increased wait times for patients, which might lead to more harm than good.

Acknowledging the challenges associated with breast MRI, the objectives of our clinical audit were successfully reached. We improved breast MRI use at our institution by accepting only evidence-based indications, and as a result, availability for this imaging modality for all women needing it was improved. By better defining high-risk patients in need of screening, clearly listing situations in which preoperative imaging could be beneficial, and eliminating MRI use where scientific evidence of benefit was not established, increased priority was given to high-risk screening studies, with improved scheduling of specific preoperative MRI evaluations.

Our expert consensus on breast MRI indications had a positive effect on wait times within the initial year of application. However, because of the high volume of pending MRI requests, with delays for non-urgent MRI exams of close to a year (320 days) at the project's onset, the effect of the new guidelines was not fully evident until the 2-year post-implementation cycle.

As soon as the consensus guidelines were introduced, compliance was high, reflecting the elevated participation rate in our multidisciplinary meeting, with at least

1 representative of each subspecialty being present. By significantly contributing to the project, all members of the breast team felt motivated to adhere to the group's consensus and to take pride in its success. Enough time was provided in the multidisciplinary consensus meeting to allow for all concerns about possible sequelae of the upcoming changes to be voiced, thus ensuring that, as soon as the consensus guidelines were introduced, they would be readily applicable for our breast centre and our patient population. Reminding the breast team and referring physicians of the consensus guidelines and making them easily available for quick reference during the daily workflow were also critical to the project's success.

Beyond our hospital, our institutional work was made available to all professionals interested in breast MRI and striving to improve their use of this technology. It also formed the basis for a first draft of provincial Quebec guidelines, mandated by the Ministère de la Santé et des Services sociaux and proposed by the Direction générale de cancérologie, with publication in May 2016[66].

CONCLUSIONS

Through collaboration by all members of the breast team, we actualized a list of breast MRI indications at our institution. Application of the resulting guidelines improved the service to women awaiting breast MRI, particularly those with a genetic predisposition, for whom annual screening is recommended. We expect to regularly update our expert consensus as new guidelines and studies are published.

Because access to technology is a constant challenge and a preoccupation in our health system and elsewhere in the world, the method we used to tackle the volume of breast MRI requests in the presence of limited technology availability could be applicable in other settings. The process of a clinical audit is relatively simple, based on multidisciplinary work and a desire to improve access for all patients.

Addendum

Since the writing of this manuscript, the results of our project have been used as the foundation of a provincial evaluation of breast MRI indications under the supervision of the Institut national d'excellence en santé et en services sociaux of Quebec.

CONFLICT OF INTEREST DISCLOSURES

We have read and understood *Current Oncology*'s policy on disclosing conflicts of interest, and we declare that we have none.

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REFERENCES

1. Wait Time Alliance. Home > Benchmarks [archival Web page]. n.l.: n.p.; 2014. [Available at: http://www.waittimealliance.ca/benchmarks/ (use caution, malware warning); cited 28 August 2016]
2. Government of Canada. *First Minister's 2004 Meeting on the Future of Health Care.* Ottawa, ON: Government of Canada; 2004. [Available online at: https://www.canada.ca/en/health-canada/services/quality-care/wait-times/first-minister-meeting-future-health-care-2004.html; cited 14 April 2017]
3. Wait Time Alliance. *Eliminating Code Gridlock in Canada's Health Care System: 2015 Wait Time Alliance Report Card.* n.l.: n.p.; 2015. [Available online at: http://www.waittimealliance.ca/wp-content/uploads/2015/12/EN-FINAL-2015-WTA-Report-Card_REV.pdf; cited 28 August 2016]
4. Podo F, Sardanelli F, Canese R, *et al.* The Italian multi-centre project on evaluation of MRI and other imaging modalities in early detection of breast cancer in subjects at high genetic risk. *J Exp Clin Cancer Res* 2002;21(suppl):115–24.
5. Kriege M, Brekelmans CT, Boetes C, *et al.* Efficacy of MRI and mammography for breast-cancer screening in women with a familial or genetic predisposition. *N Engl J Med* 2004;351:427–37.
6. Warner E, Plewes DB, Hill KA, *et al.* Surveillance of *BRCA1* and *BRCA2* mutation carriers with magnetic resonance imaging, ultrasound, mammography, and clinical breast examination. *JAMA* 2004;292:1317–25.
7. Kuhl CK, Schrading S, Leutner CC, *et al.* Mammography, breast ultrasound, and magnetic resonance imaging for surveillance of women at high familial risk for breast cancer. *J Clin Oncol* 2005;23:8469–76.
8. Lehman CD, Blume JD, Thickman D, *et al.* Added cancer yield of MRI in screening the contralateral breast of women recently diagnosed with breast cancer: results from the International Breast Magnetic Resonance Consortium (IBMC) trial. *J Surg Oncol* 2005;92:9–15.
9. Leach MO, Boggis CR, Dixon AK, *et al.* Screening with magnetic resonance imaging and mammography of a U.K. population at high familial risk of breast cancer: a prospective multicentre cohort study (MARIBS). *Lancet* 2005;365:1769–78.
10. Lehman CD, Isaacs C, Schnall MD, *et al.* Cancer yield of mammography, MR, and US in high-risk women: prospective multi-institution breast cancer screening study. *Radiology* 2007;244:381–8.
11. Sardanelli F, Podo F, D'Agnolo G, *et al.* Multicenter comparative multimodality surveillance of women at genetic-familial high risk for breast cancer (HIBCRIT study): interim results. *Radiology* 2007;242:698–715.
12. Stout NK, Nekhlyudov L, Li L, *et al.* Rapid increase in breast magnetic resonance imaging use: trends from 2000 to 2011. *JAMA Intern Med* 2014;174:114–21.
13. Nessim C, Winocour J, Holloway DP, Saskin R, Holloway CM. Wait times for breast cancer surgery: effect of magnetic resonance imaging and preoperative investigations on the diagnostic pathway. *J Oncol Pract* 2015;11:e131–8.
14. Arnaout A CC, Booth CM, McInnes M, *et al.* Use of preoperative magnetic resonance imaging for breast cancer: a Canadian population-based study. *JAMA Oncol* 2015;1:1238–50.
15. Houssami N, Turner R, Morrow M. Preoperative magnetic resonance imaging in breast cancer: meta-analysis of surgical outcomes. *Ann Surg* 2013;257:249–55.
16. Bankhead C. Breast MRI use up despite lack of indications [Web article]. Little Falls, NJ: MedPage Today; 2013. [Available at: http://www.medpagetoday.com/HematologyOncology/BreastCancer/42978; cited 28 August 2016]
17. Wernli KJ, DeMartini WB, Ichikawa L, *et al.* Patterns of breast magnetic resonance imaging use in community practice. *JAMA Intern Med* 2014;174:125–32.
18. Hwang ES, Bedrosian I. Patterns of breast magnetic resonance imaging use: an opportunity for data-driven resource allocation. *JAMA Intern Med* 2014;174:122–4.
19. Canadian Association of Radiologists (CAR). *National Maximum Wait Time Access Targets for Medical Imaging.* Ottawa, ON: CAR; 2013: 3.

20. Solin LJ, Orel SG, Hwang WT, Harris EE, Schnall MD. Relationship of breast magnetic resonance imaging to outcome after breast-conservation treatment with radiation for women with early-stage invasive breast carcinoma or ductal carcinoma *in situ*. *J Clin Oncol* 2008;26:386–91.
21. Turnbull L, Brown S, Harvey I, *et al.* Comparative effectiveness of MRI in breast cancer (COMICE) trial: a randomised controlled trial. *Lancet* 2010;375:563–71.
22. Houssami N, Turner R, Macaskill P, *et al.* An individual person data meta-analysis of preoperative magnetic resonance imaging and breast cancer recurrence. *J Clin Oncol* 2014;32:392–401.
23. Hwang N, Schiller DE, Crystal P, Maki E, McCready DR. Magnetic resonance imaging in the planning of initial lumpectomy for invasive breast carcinoma: its effect on ipsilateral breast tumor recurrence after breast-conservation therapy. *Ann Surg Oncol* 2009;16:3000–9.
24. Bedrosian I, Suman VJ, Yao K, *et al.* ACOSOG Z11101/ACRIN 6694: effect of preoperative breast MRI on surgical outcomes, costs and quality of life of women with breast cancer [abstract OT2-05-06]. *Cancer Res* 2011;71(suppl):.
25. Millar EK, Graham PH, O'Toole SA, *et al.* Prediction of local recurrence, distant metastases, and death after breast-conserving therapy in early-stage invasive breast cancer using a five-biomarker panel. *J Clin Oncol* 2009;27:4701–8.
26. Voduc KD, Cheang MCU, Tyldesley S, Gelmon K, Nielsen TO, Kennecke H. Breast cancer subtypes and the risk of local and regional relapse. *J Clin Oncol* 2010;28:1684–91.
27. Woods R, Gelmon KA, Tyldesley S, Kennecke HF, Speers C, Yerushalmi R. Impact of mulitfocal/multicentric versus unifocal breast cancer on local recurrence [abstract 514]. *J Clin Oncol* 2010;28:. [Available online at: http://meetinglibrary.asco.org/content/54521-74; cited 14 April 2017]
28. Mann R, Veltman J, Barentsz JO, Wobbes T, Blickman JG, Boetes C. The value of MRI compared to mammography in the assessment of tumour extent in invasive lobular carcinoma of the breast. *Eur J Surg Oncol* 2008;34:135–42.
29. Mann RM, Loo CE, Wobbes T, *et al.* The impact of preoperative breast MRI on the re-excision rate in invasive lobular carcinoma of the breast. *Breast Cancer Res Treat* 2009;119:415–22.
30. Bluemke DA, Gatsonis CA, Chen MH, *et al.* Magnetic resonance imaging of the breast prior to biopsy. *JAMA* 2004;292:2735–42.
31. Marinovich ML, Macaskill P, Irwig L, *et al.* Meta-analysis of agreement between MRI and pathologic breast tumour size after neoadjuvant chemotherapy. *Br J Cancer* 2013;109:1528–36.
32. Brennan ME, Houssami N, Lord S, *et al.* Magnetic resonance imaging screening of the contralateral breast in women with newly diagnosed breast cancer: systematic review and meta-analysis of incremental cancer detection and impact on surgical management. *J Clin Oncol* 2009;27:5640–9.
33. Lehman CD, Gatsonis C, Kuhl CK, *et al.* MRI evaluation of the contralateral breast in women with recently diagnosed breast cancer. *N Engl J Med* 2007;356:1295–303.
34. American Society of Breast Surgeons. *Position Statement on the Use of Magnetic Resonance Imaging in Breast Surgical Oncology.* Columbia, MD: American Society of Breast Surgeons; 2010. [Available online at: https://www.breastsurgeons.org/new_layout/about/statements/PDF_Statements/MRI.pdf; cited 28 August 2016]
35. BC Cancer Agency (BCCA). 4.2 MRI (Magnetic Resonance Imaging) [Web page subsection]. Vancouver, BC: BCCA; 2009. [Available online at: http://www.bccancer.bc.ca/health-professionals/professional-resources/cancer-management-guidelines/breast/breast#MRI-(Magnetic-Resonance-Imaging); cited 21 April 2017]
36. National Comprehensive Cancer Network (NCCN). *NCCN Clinical Practice Guidelines in Oncology: Breast Cancer.* Ver. 2.2017. Fort Washington, PA: NCCN; 2017. [Current version available online at: https://www.nccn.org/professionals/physician_gls/pdf/breast.pdf (free registration required); cited 21 April 2017]
37. Sardanelli F, Boetes C, Borisch B, *et al.* Magnetic resonance imaging of the breast: recommendations from the EUSOMA working group. *Eur J Cancer* 2010;46:1296–316.
38. Canadian Association of Radiologists (CAR). *CAR Practice Guidelines and Technical Standards for Breast Imaging and Intervention.* Ottawa, ON: CAR; 2012.
39. Argus A, Mahoney MC. Clinical indications for breast MRI. *Appl Radiol* 2010;39:10–19.
40. Cancer Care Ontario (CCO). Breast Cancer Screening [Web page]. Toronto, ON: CCO; 2013. [Current version available at: https://www.cancercare.on.ca/pcs/screening/breastscreening; cited 28 August 2016]
41. U.K. National Institute for Health and Care Excellence (NICE). Quality statement 2: Preoperative MRI scan [Web page]. London, U.K.: NICE; 2013. [Current version available at: https://www.nice.org.uk/guidance/qs12/chapter/Quality-statement-2-Preoperative-MRI-scan; cited 28 August 2016]
42. Mann RM, Kuhl CK, Kinkel K, Boetes C. Breast MRI: guidelines from the European Society of Breast Imaging. *Eur Radiol* 2008;18:1307–18.
43. Alberta Health Services (AHS). *Magnetic Resonance Imaging for Breast Cancer Screening, Pre-operative Assessment, and Follow-Up.* Clinical practice guideline BR-007. Ver. 2. Edmonton, AB: AHS; 2012. [Available online at: http://www.albertahealthservices.ca/assets/info/hp/cancer/if-hp-cancer-guide-br007-mri.pdf; cited 28 August 2016]
44. Saslow D, Boetes C, Burke W, *et al.* on behalf of the American Cancer Society Breast Cancer Advisory Group. American Cancer Society guidelines for breast screening with MRI as an adjunct to mammography. *CA Cancer J Clin* 2007;57:75–89. [Erratum in: *CA Cancer J Clin* 2007;57:185]
45. American College of Radiology (ACR). *ACR Appropriateness Criteria: Breast Cancer Screening.* Reston, VA: ACR; 2013.
46. Bennett IC, Muller J, Cockburn L, *et al.* Outcomes of multimodality breast screening for women at increased risk of familial breast cancer. *World J Surg* 2010;34:979–86.
47. Robson M, Offit K. Clinical practice. Management of an inherited predisposition to breast cancer. *N Engl J Med* 2007;357:154–62.
48. Berg WA. Tailored supplemental screening for breast cancer: what now and what next? *AJR Am J Roentgenol* 2009;192:390–9.
49. Zakhireh J, Fowble B, Esserman LJ. Application of screening principles to the reconstructed breast. *J Clin Oncol* 2010;28:173–80.
50. Pinel-Giroux FM, El Khoury MM, Trop I, Bernier C, David J, Lalonde L. Breast reconstruction: review of surgical methods and spectrum of imaging findings. *Radiographics* 2013;33:435–53.
51. Vanderwalde LH, Dang CM, Tabrizi R, Saouaf R, Phillips EH. Breast MRI after bilateral mastectomy: is it indicated? *Am Surg* 2011;77:180–4.
52. Pijpe A, Andrieu N, Easton DF, *et al.* on behalf of GENEPSO, EMBRACE, and HEBON. Exposure to diagnostic radiation and risk of breast cancer among carriers of *BRCA1/2* mutations: retrospective cohort study (GENE-RAD-RISK). *BMJ* 2012;345:e5660.
53. Griepsma M, de Roy van Zuidewijn DB, Grond AJ, Siesling S, Groen H, de Bock GH. Residual breast tissue after mastectomy: how often and where is it located? *Ann Surg Oncol* 2014;21:1260–6.
54. Houssami N, Abraham LA, Miglioretti DL, *et al.* Accuracy and outcomes of screening mammography in women with

a personal history of early-stage breast cancer. *JAMA* 2011;305:790–9.
55. Robertson C, Ragupathy SK, Boachie C, *et al.* on behalf of the Mammographic Surveillance Health Technology Assessment Group. Surveillance mammography for detecting ipsilateral breast tumour recurrence and metachronous contralateral breast cancer: a systematic review. *Eur Radiol* 2011;21:2484–91.
56. Chia SK, Wolff AC. With maturity comes confidence: EBCTCG tamoxifen update. *Lancet* 2011;378:747–9.
57. Chia S, Bryce C, Gelmon K. The 2000 EBCTCG overview: a widening gap. *Lancet* 2005;365:1665–6.
58. Gorechlad JW, McCabe EB, Higgins JH, *et al.* Screening for recurrences in patients treated with breast-conserving surgery: is there a role for MRI? *Ann Surg Oncol* 2008;15:1703–9.
59. Brennan S, Liberman L, Dershaw DD, Morris E. Breast MRI screening of women with a personal history of breast cancer. *AJR Am J Roentgenol* 2010;195:510–16.
60. Friedlander LC, Roth SO, Gavenonis SC. Results of MR imaging screening for breast cancer in high-risk patients with lobular carcinoma *in situ*. *Radiology* 2011;261:421–7.
61. Sung JS, Malak SF, Bajaj P, Alis R, Dershaw DD, Morris EA. Screening breast MR imaging in women with a history of lobular carcinoma *in situ*. *Radiology* 2011;261:414–20.
62. Bennett IC, Muller J, Cockburn L, *et al.* Outcomes of multimodality breast screening for women at increased risk of familial breast cancer. *World J Surg* 2010;34:979–86.
63. American College of Radiology (ACR). *ACR Practice Parameter for the Performance of Contrast-Enhanced Magnetic Resonance Imaging (MRI) of the Breast.* Reston, VA: ACR; 2014.
64. Bleicher RJ. Breast magnetic resonance imaging as it is, in contrast to how we wish it to be. *J Clin Oncol* 2014;32:370–2.
65. Canadian Medical Association (CMA). Choosing wisely Canada [Web resource]. Toronto, ON: CMA; 2016. [Available at: http://www.choosingwiselycanada.org; cited 16 April 2016]
66. Ministère de la Santé et des Services sociaux (MSSS). *Recommandations sur l'utilisation de l'imagerie par résonance magnétique dans le diagnostic et le traitement du cancer du sein et pour la surveillance active chez les femmes à risque.* Québec, QC: La Direction des communications du ministère de la Santé et des Services sociaux; 2016: 15.