Radiology

REVIEWS AND COMMENTARY • REVIEW

Abbreviated Breast MRI: State of the Art

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Conflicts of interest are listed at the end of this article.

Radiology 2024; 310(3):e221822 • https://doi.org/10.1148/radiol.221822 • Content codes: BR MR

Abbreviated MRI is an umbrella term, defined as a focused MRI examination tailored to answer a single specific clinical question. For abbreviated breast MRI, this question is: "Is there evidence of breast cancer?" Abbreviated MRI of the breast makes maximum use of the fact that the kinetics of breast cancers and of benign tissue differ most in the very early postcontrast phase; therefore, abbreviated breast MRI focuses on this period. The different published approaches to abbreviated MRI include the following three subtypes: *(a)* short protocols, consisting of a precontrast and either a single postcontrast acquisition (first postcontrast subtracted [FAST]) or a time-resolved series of postcontrast acquisitions with lower spatial resolution (ultrafast [UF]), obtained during the early postcontrast phase immediately after contrast agent injection; *(b)* abridged protocols, consisting of FAST or UF acquisitions plus selected additional pulse sequences; and *(c)* noncontrast protocols, where diffusion-weighted imaging replaces the contrast information. Abbreviated MRI was proposed to increase tolerability of and access to breast MRI as a screening tool. But its widening application now includes follow-up after breast cancer and even diagnostic assessment. This review defines the three subtypes of abbreviated MRI, highlighting the differences between the protocols and their clinical implications and summarizing the respective evidence on diagnostic accuracy and clinical utility.

MRI is one of the most powerful imaging methods of contemporary medicine (1). Efforts are ongoing to provide even more varieties of image contrast, more functional information, and reduce acquisition times of established pulse sequences. The latter led to the introduction of parallel imaging (sensitivity encoding) (2), data sparsity imaging (compressed sensing) (3), and, recently, artificial intelligence–based image reconstruction (4). This, together with greatly increased computing power and thus reconstruction speed, has accelerated image acquisition. And yet, time slots reserved for MRI examinations have remained fairly constant, at least in academic departments (5,6). Hence, faster acquisition strategies have apparently mainly been invested to acquire more comprehensive diagnostic information. This may perpetuate the perception of MRI as a complex third-line imaging method, limiting access to MRI in many clinical settings where it could be beneficial. This is where abbreviated MRI comes in.

Rationale for Abbreviated MRI

Abbreviated MRI is an umbrella term. It is defined as a focused version of an MRI examination, tailored to answer a single specific clinical question. The first clinical application was on the breast. But from the outset, the expectation was translation to other organ systems (7,8). Current clinical applications include screening or surveillance of prostate (8,9), liver (10), and rectal (11) cancers, and cystic pancreatic lesions (12), as well as for acute trauma (13) and diagnostic MRI in pediatric patients to avoid sedation (14). Accordingly, abbreviated MRI is meant to amend, not replace, the current way we use MRI in clinical practice. The overall goal is to expand the role of MRI to clinical applications once thought inconceivable for reasons of cost, capacity, and/or patient tolerability.

Abbreviated breast MRI was first proposed as a method to increase access to MRI screening (15). The specific clinical question to answer is: "Is there evidence of breast cancer?" Screening means sieving a large cohort of healthy individuals to identify the few who may have cancer. To be practicable, tolerable, and affordable on a population-wide scale, screening should consist of acceptably convenient procedures that are fast and easy to perform and interpret—quite the opposite of conventional breast MRI protocols.

Abbreviated MRI introduces what one could call a "pulse sequence economy." It promotes focusing on the few pulse sequences that provide the highest (diagnostic) return on (magnet and reader time) investment. The question is then: "What components of breast MRI protocols are essential to identify breast cancer?" This decision, in turn, is guided by the question: "What is the most powerful diagnostic information to be worked out?"

Diagnostic criteria in breast MRI are based on the assessment of contrast enhancement. Even when using the Breast Imaging Reporting and Data System (BI-RADS) lexicon to describe lesion morphologic characteristics, we refer to the morphologic characteristics of only the enhancing part of a given lesion (16). Accordingly, contrast enhancement is the key feature for detection and classification of lesions. For the assessment of morphologic details of enhancing tissues, high spatial resolution is an obvious requirement. Of similar importance, however, is high contrast (ie, high signal intensity difference) between the enhancing tumor and its background of normal fibroglandular tissue (ie, background parenchymal enhancement [BPE]). In cancers with persistent enhancement and very low BPE levels, lesion-to-background contrast may increase over the postcontrast period. However, usually this contrast is highest in the early postcontrast phase,

Abbreviations

BPE = background parenchymal enhancement, DBT = digital breast tomosynthesis, DCE = dynamic contrast-enhanced, DWI = diffusion-weighted imaging, FAST = first postcontrast subtracted, UF = ultrafast

Summary

An umbrella term, abbreviated MRI is a focused version of an MRI examination, tailored to answer a single specific clinical question—for abbreviated breast MRI, this is whether there is evidence of breast cancer—and through intelligent selective pulse sequences, intends to maximize diagnostic "return" on magnet and radiologist time "investment."

Essentials

- Abbreviated MRI means using MRI in a more targeted way; rather than a simple truncation of traditional pulse sequence protocols, it promotes selective use of pulse sequences that are sufficient to answer a single specific clinical question.
- Abbreviated MRI has been proposed to increase access to and tolerability of breast cancer screening or surveillance; published indications also include diagnostic assessment, such as management of equivocal microcalcifications, and preoperative local staging.
- Three subtypes of abbreviated breast MRI protocols are as follows: *(a)* short protocols, consisting of a precontrast and either a single postcontrast acquisition (first postcontrast subtracted [FAST]) or a time-resolved series of postcontrast acquisitions with lower spatial resolution (ultrafast [UF]), both obtained during the early postcontrast phase; *(b)* abridged protocols, consisting of FAST or UF plus selected additional pulse sequences; and *(c)* abridged noncontrast protocols.
- The diagnostic accuracies associated with the different short and abridged protocols are equivalent to those of the respective full protocols; data on noncontrast abbreviated protocols are not yet available.
- Abbreviated MRI with abridged protocols has successfully been used within clinical trials as a standalone method for screening, surveillance, and staging; most evidence exists for the combination of FAST plus T2-weighted imaging.

diminishing thereafter due to washout or plateau enhancement of invasive cancers and progressively increasing BPE (Figs 1, 2). Accordingly, the early postcontrast phase, defined as the first 60 seconds after contrast agent injection, is the cornerstone of breast cancer detection and classification in breast MRI, be it in full or abbreviated protocols.

Taxonomy of Abbreviated Protocols

Therefore, the first approach to abbreviated breast MRI was to focus on the early postcontrast period and use high-spatial-resolution imaging to characterize lesions with fast and strong enhancement based on their morphologic features (Fig 3) (7). This approach was named first postcontrast subtracted (FAST) MRI.

Since then, many studies with variable acquisition protocols have been published under the name "abbreviated MRI." However, what defined abbreviated MRI in the respective studies ranged from "shorter than one's own regular protocol" to "any protocol with only one postcontrast acquisition" (ie, nondynamic imaging), to "any protocol that takes less than 10 minutes." These definitions are not in agreement with the concept of abbreviated MRI as discussed above. Rather than a simple truncation of traditional protocols, abbreviated MRI implies an intelligent and selective use of MRI pulse sequences.

The notion that abbreviated MRI would imply nondynamic imaging led to the misconception that abbreviated MRI would abandon using enhancement kinetics for differential diagnosis in breast MRI. Rather, abbreviated MRI takes maximum advantage of enhancement kinetics of benign and malignant lesions, which differ most in the early postcontrast phase (17). All imaging criteria for enhancement kinetics used for regular dynamic contrast-enhanced (DCE) breast MRI may also be used for interpretation of abbreviated MRI. The only kinetic information lost specifically with short-protocol subtypes of abbreviated MRI (explained herein) is that of late-phase enhancement, and even this kinetic information is at least partly retained with other subtypes of abbreviated MRI (18).

Confusion can also be caused when the terms "abbreviated MRI" and "ultrafast MRI" (19), hereafter UF MRI, are used as if they represent similar approaches (20), with UF being "faster than FAST." In fact, UF MRI means to continuously monitor contrast enhancement during the wash-in phase through time-resolved imaging. Thus, FAST and UF MRI require about the same acquisition time; both are acquired before and during the early postcontrast phase, during which either a single high-spatial-resolution image is generated (FAST) or many lower-resolution images (UF). UF MRI is not abbreviated MRI, but is a pulse sequence that has so far mainly been used as a component of conventional breast MRI protocols (Fig 4–6).

To provide some guidance for future communication and research, the following terminology is recommended (Fig 5).

A full breast MRI protocol consists of a DCE series (ie, one precontrast and several postcontrast acquisitions covering also the late postcontrast period, with or without an integrated UF series). In addition, T2-weighted sequences with and/or without fat suppression, plus additional planes, are acquired. Full protocols that acquire additional functional information (eg, by diffusion-weighted imaging [DWI]) are "multiparametric." Both full and multiparametric protocols can be categorized as conventional breast MRI. In this context, conventional does not refer to the acquisition method, which can be novel or experimental, but denotes the philosophy of MRI use, where the examination is meant to maximize diagnostic information for a given patient.

Abbreviated protocols, on the other hand, can be subdivided into the following three subtypes: short protocols, abridged protocols, and noncontrast protocols.

Short Protocols

FAST MRI.—With FAST MRI, the acquisition protocol is simple (Fig 6) and limited to one precontrast and one postcontrast T1-weighted acquisition with identical spatial resolution and geometry (Figs 3, 7). The postcontrast sequence must start immediately after injection of the contrast agent and the saline flush. The acquisition time must be short enough to capture the early postcontrast period (ie, approximately 60 seconds), in agreement with Kaiser and Zeitler's concept of DCE MRI (17). Spatial resolution must be high enough to resolve small

anatomic details. Our institutional protocol offers a noninterpolated in-plane resolution of 0.6 × 0.6 mm and a section thickness of 2–3 mm (21).

For our FAST protocol, we prefer the axial orientation. This allows bilateral imaging with the lowest possible number of sections and with direct side-by-side comparison of both breasts, which is helpful for characterizing non–mass enhancement (22).

We do not use active fat suppression. Instead, we deliberately retain the signal from fat to exploit the MRI signal and the morphologic (architectural) information it provides (Fig 7). On non–fat-suppressed precontrast T1-weighted and/or T2-weighted images, fat helps assess tumor margins and their growth patterns with regards to Cooper ligaments, similar to mammography or digital breast tomosynthesis (DBT), where fat is the only "contrast agent" that enables this assessment. Moreover, fat yields high signal intensity in T1- and T2-weighted imaging, thus improving the overall image signal to noise ratio, which is an important aspect in fast dynamic imaging.

Selective visualization of enhancement is achieved by subtraction. Subtraction is needed regardless of whether breast MRI is acquired with or without active fat suppression. This is because, in acquisitions with active fat suppression, tissues with a short T1 relaxation time (eg, proteinaceous fluid in cysts or dilated ducts) will yield high signal intensity that can mimic enhancement.

To improve subtraction, we gently fixate the breast in the craniocaudal direction. This also reduces the breast volume in the slice-encoding direction. Thus, in our FAST protocol, 25–31 sections suffice to cover the breast, which helps reduce both acquisition time (with two-dimensional multislice imaging) and radiologist reading time.

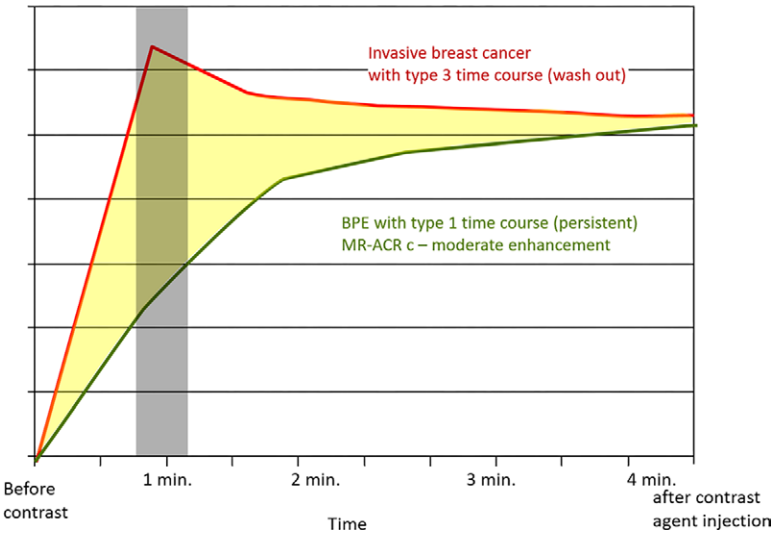

Figure 1: Graph shows enhancement patterns of breast cancer and normal tissue, and its implication for abbreviated breast MRI. The early and fast enhancement of breast cancers in the initial postcontrast phase is frequently followed by a washout (ie, loss of signal intensity) after the initial phase. Normal fibroglandular tissue exhibits steady (persistent) enhancement. The signal intensity difference (yellow) between breast cancer and normal fibroglandular tissue is highest during the immediate postinjection period (gray) and will decrease during later phases. The "c" denotes moderate enhancement of normal fibroglandular tissue at MRI. ACR = American College of Radiology, BPE = background parenchymal enhancement.

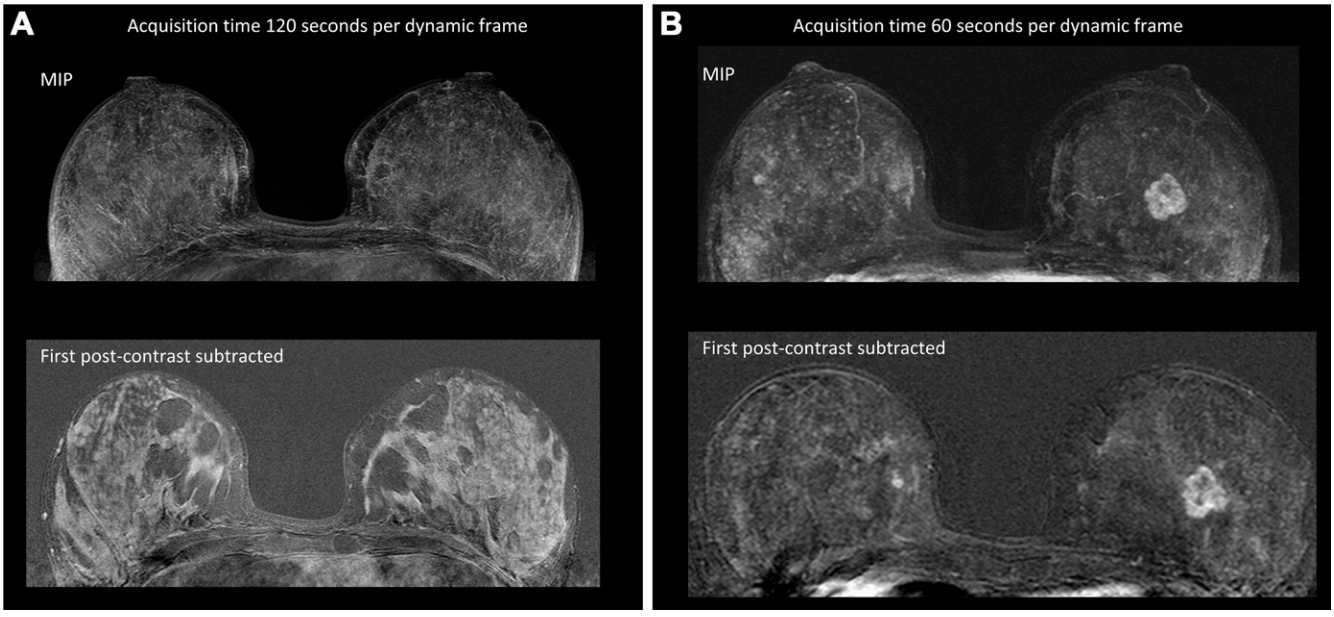

Figure 2: Breast MRI in a 44-year-old female patient with biopsy-proven cancer in the left breast, who underwent preoperative dynamic contrast-enhanced imaging for staging twice, shows the impact of temporal resolution on detectability of cancer. **(A)** Images acquired with high spatial resolution and low temporal resolution (120 seconds per dynamic frame) show the cancer is barely visible. **(B)** Images acquired the next day with lower spatial and higher temporal resolution (60 seconds per dynamic frame) show the cancer is perfectly visible. Note that, due to early and strong washout of the cancer combined with strong background parenchymal enhancement (BPE), the contrast between the cancer and adjacent normal tissue is cancelled out already at 120 seconds after contrast agent injection in the high spatial and low temporal resolution acquisition in **A**. When the patient was called back and breast MRI with a temporal resolution of 60 seconds was used **(B)**, the cancer appeared at its peak enhancement and BPE was still low or absent. MIP = maximum intensity projection.

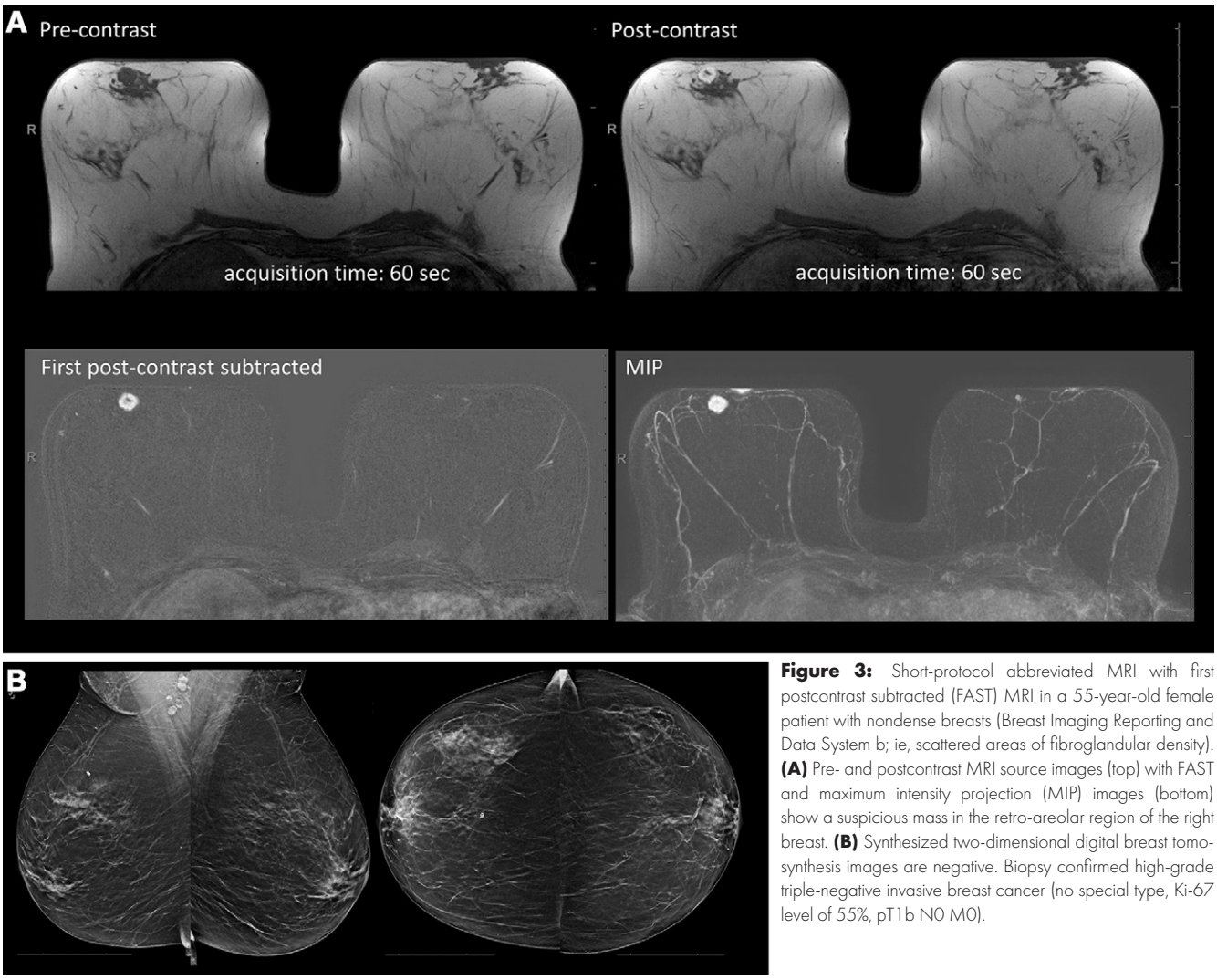

Figure 3: Short-protocol abbreviated MRI with first postcontrast subtracted (FAST) MRI in a 55-year-old female patient with nondense breasts (Breast Imaging Reporting and Data System b; ie, scattered areas of fibroglandular density). **(A)** Pre- and postcontrast MRI source images (top) with FAST and maximum intensity projection (MIP) images (bottom) show a suspicious mass in the retro-areolar region of the right breast. **(B)** Synthesized two-dimensional digital breast tomosynthesis images are negative. Biopsy confirmed high-grade triple-negative invasive breast cancer (no special type, Ki-67 level of 55%, pT1b N0 M0).

Postcontrast subtracted images are fused to a single maximum intensity projection (MIP). These MIPs can be helpful to quickly sort out negative screening studies (eg, in a population screening setting). However, MIPs are quasi-summation images. They do not allow an analysis of lesion margins or internal architecture, which is the domain of cross-sectional imaging (FAST images and their respective nonsubtracted source images). Moreover, whenever there is patient motion, subtraction artifacts can degrade MIP reconstructions. Because MIPs are not sufficient to establish a final diagnosis, it is inappropriate to report on diagnostic accuracies of MIP interpretation alone.

UF MRI.—UF MRI means MR imaging with very high temporal resolution before and during the first 1–2 minutes after contrast agent injection (ie, during the wash-in phase). Images are acquired continuously every 3–6 seconds per dynamic frame for approximately 20 dynamic frames (ie, approximately 60–120 seconds) (Fig 6). UF MRI uses methods developed for time-resolved MR angiography, such as TWIST (time-resolved angiography with interleaved stochastic trajectories), TRICKS (time-resolved imaging of contrast kinetics), or four-dimensional TRAK (time-resolved MR angiography with keyhole) (19,23). A common principle of these time-resolved approaches is that the contrast information is collected at each time point, whereas the spatial information is successively sampled over several consecutive dynamic frames, which is a principle called "view sharing" or "keyhole" (24).

Like conventional DCE breast MRI (or its abbreviated version, FAST), UF MRI exploits the fact that enhancement kinetics of normal and/or benign tissues and that of malignant lesions differ most during the early postcontrast phase. In UF MRI, the main kinetic criteria are the time it takes for a lesion to start enhancement relative to the opacification of the thoracic aorta and the slope of the enhancement curve (19,25), although many more kinetic features are derivable from the acquired data sets (26–31).

A downside of UF MRI is that the resulting spatial resolution is not always satisfactory. High acceleration factors, view sharing, and compressed sensing methods can lead to image blurring. This may explain why, so far, UF MRI has mostly been used within DCE protocols or framed by additional precontrast and postcontrast high-spatial-resolution acquisitions (27). Thus, UF MRI offers powerful additional kinetic criteria for differential diagnosis, yet possibly at the expense of the ability to judge lesion morphologic features (Fig 4).

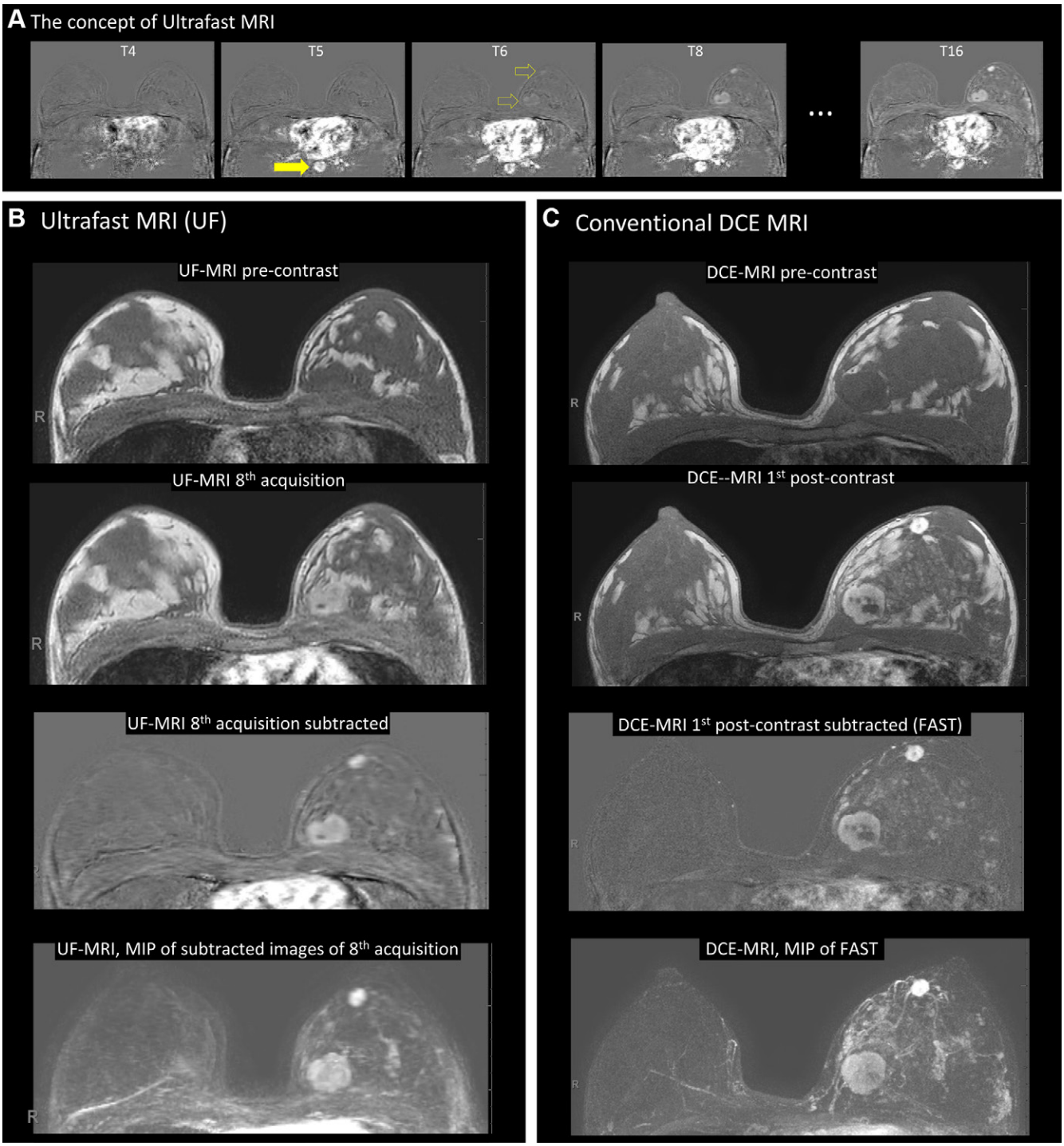

Figure 4: Breast MRI in a 38-year-old female patient who underwent contrast-enhanced imaging twice, once with regular dynamic contrast-enhanced (DCE) MRI and, on the next day, with ultrafast (UF) MRI. The patient had triple-negative breast cancer in the back of the left breast, a second breast cancer (no special type, luminal B, G3) in the retro-areolar region, and extensive high-grade ductal carcinoma in situ. **(A)** UF images acquired with a temporal resolution of 3.5 seconds per frame over 16 dynamic frames show opacification of the right ventricle in the fourth dynamic frame (T4) and opacification of the descending aorta in the fifth dynamic frame (T5, arrow). The cancer starts to enhance already on the next frame (T6, arrows) and there is peak enhancement in both cancers at T8, which is two dynamic frames, or 7 seconds, after opacification of the aorta. Non–mass enhancement due to extensive ductal carcinoma in situ occurs only later. **(B, C)** Images show a comparison of image quality in UF MRI **(B)** versus conventional DCE MRI with first postcontrast subtracted (FAST) imaging **(C)**. Note the blurred lesion contours on UF images, and similar cancer-to-background contrast on the UF and FAST images. MIP = maximum intensity projection.

It is due to the introduction of UF MRI, however, that the radiologic community rediscovered the importance of early time-resolved imaging for breast MRI. From its outset, conventional DCE breast MRI also had been recommended with the highest achievable temporal resolution, which at the time of Kaiser and Zeitler (17) had been 60 seconds per dynamic frame. Over the decades, many breast MRI protocols accepted longer acquisition times (ie, accepted a lower temporal

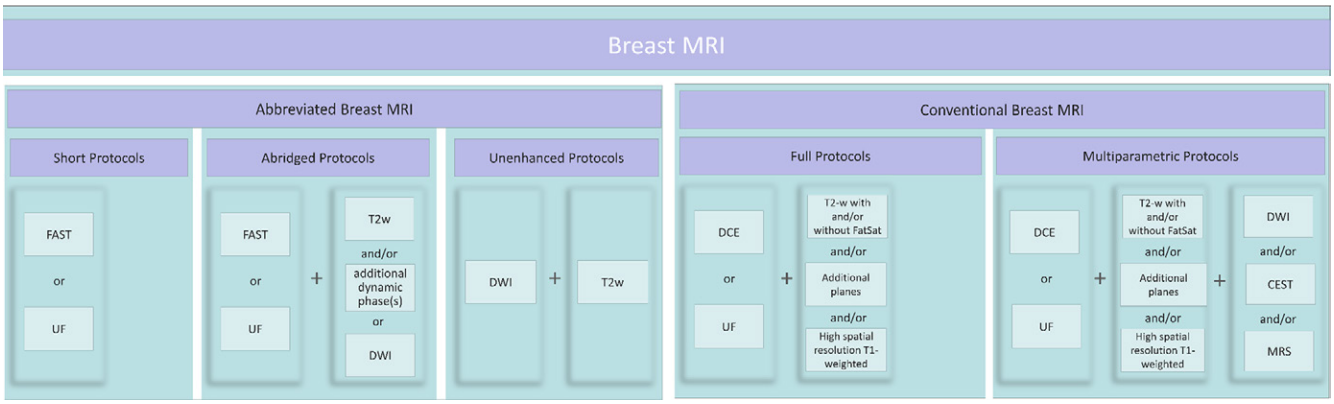

Figure 5: Graphic shows a proposed classification system of breast MRI acquisition strategies. CEST = chemical exchange saturation transfer, DCE = dynamic contrast-enhanced, DWI = diffusion-weighted imaging, FAST = first postcontrast subtracted, FatSat = fat saturation, MRS = MR spectroscopy, T2w = T2-weighted imaging, UF = ultrafast.

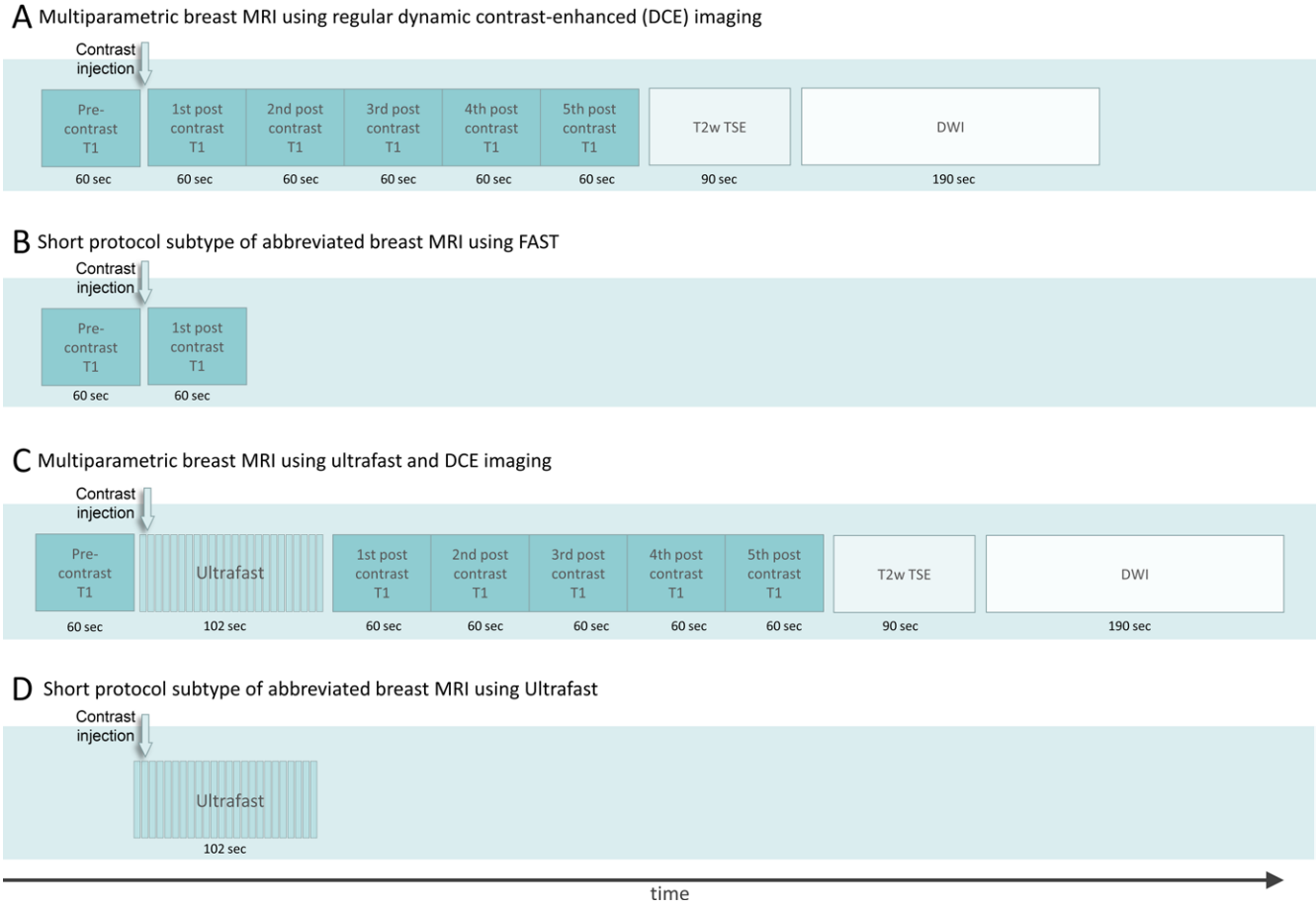

Figure 6: Graphic shows a comparison of multiparametric breast MRI using **(A)** "regular" dynamic contrast-enhanced (DCE) MRI versus **(B)** short-protocol breast MRI based on DCE MRI (ie, first postcontrast subtracted [FAST]), **(C)** multiparametric breast MRI using ultrafast (UF) MRI, and **(D)** short-protocol breast MRI using UF MRI. DWI = diffusion-weighted imaging, TSE = turbo spin echo, T2w = T2-weighted.

resolution) in order to increase their spatial resolution. Many current protocols take 120 seconds per dynamic frame, or more, and/or delay the postcontrast acquisitions. Thus, the respective first postcontrast images are acquired when BPE and/or washout of invasive cancers can already be substantial (Fig 1). Strong BPE can both mask and mimic malignant lesions. The masking effect of BPE can be aggravated when there is also early washout, which is observed especially in aggressive cancers (Fig 2). Methods that capture the early postcontrast phase, such as UF MRI or conventional DCE MRI protocols that adhere to the recommendations of Kaiser and Zeitler, effectively avoid BPE. Thus, UF MRI and such DCE MRI protocols will

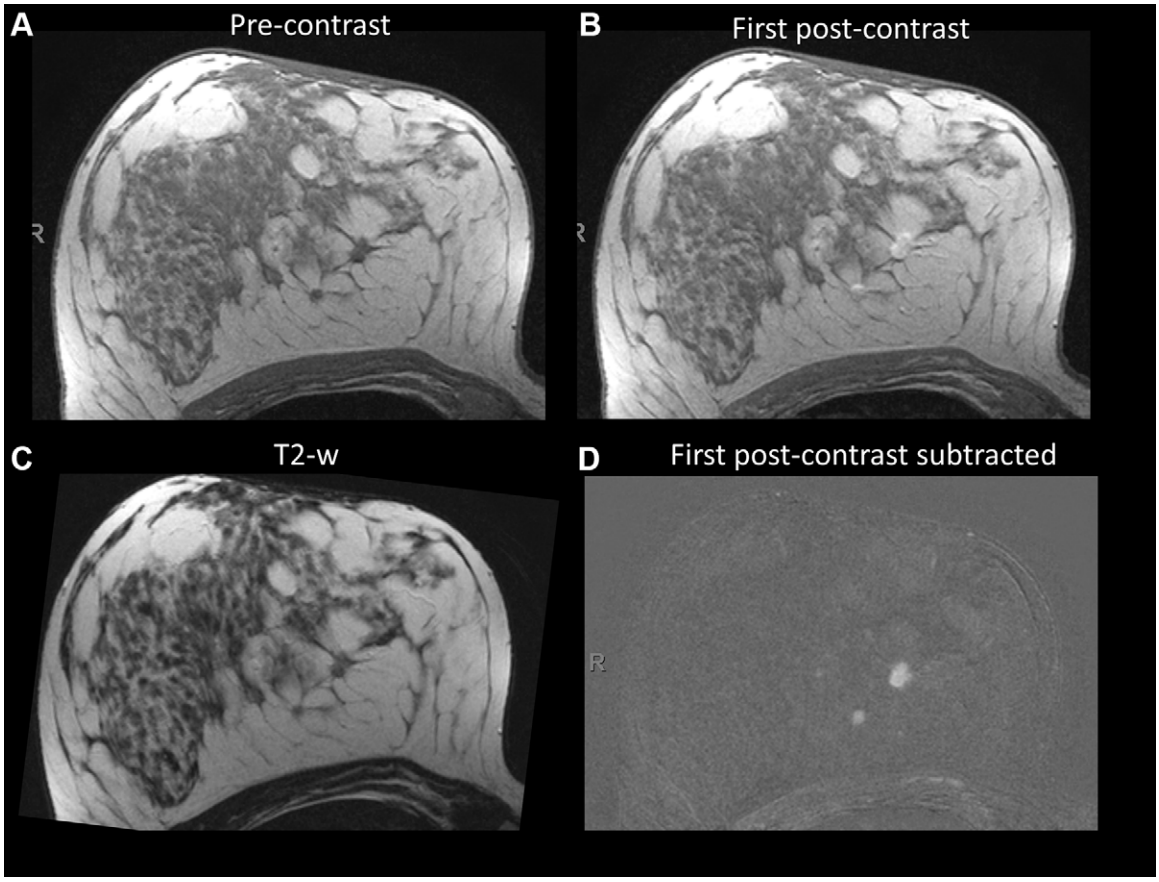

Figure 7: **(A–D)** Abridged-protocol abbreviated MRI with first postcontrast subtracted (FAST) plus T2-weighted imaging in a 52-year-old female patient with bifocal invasive breast cancer (no special type, G2, pT1b-m) shows the value of retaining fat signal. The subtraction image **(D)** shows an apparently oval well-circumscribed enhancing mass with fairly smooth margins and homogeneous enhancement, and a small satellite. The non–fat-suppressed precontrast image **(A)**, as well as the non–fat-suppressed T2-weighted image **(C)**, show the architectural distortion and nonenhancing spicules.

be similarly useful to help avoid missing the peak enhancement of cancers, as well as the masking effect of BPE; both, therefore, will ensure a more selective visualization of malignant lesions for improved sensitivity and specificity.

FAST or UF?—UF MRI is an emerging method. Current research mainly investigates its use as a component of full or multiparametric protocols. Recent examples are the study by Ramtohul et al (26) on assessing systemic treatment response and the study by Miceli et al (31) on predicting upgrade to invasive cancer in patients with ductal carcinoma in situ. Published evidence on UF MRI as a standalone method for abbreviated MRI consists of, so far, four retrospective studies involving 479 patients (28–30,32). In comparison, the diagnostic accuracy of FAST for abbreviated MRI has been tested in 16 prospective or retrospective studies involving 5074 individuals.

UF MRI again adds complexity to image acquisition and image interpretation, whereas one important objective of introducing abbreviated MRI has been to facilitate a simple and short screening method. In addition, UF MRI requires cutting edge MRI technology with regards to system software and hardware, whereas the technology required for FAST is available on basic MRI systems.

Abridged-Protocol MRI

Abridged-protocol MRI means to carefully select additional pulse sequences beyond the core (ie, the precontrast plus early postcontrast acquisitions obtained with FAST or UF MRI). The question is then: "Which pulse sequence to add?"

Published abridged short protocols add T2-weighted imaging or DWI, and/or additional postcontrast dynamic acquisition(s), the latter termed rapid abridged multiphase (RAMP) (18). The RAMP protocol enables retaining some of the differential diagnostic information provided by time–signal intensity curve analysis. Washout of cancer occurs immediately after peak enhancement, approximately 90–120 seconds after contrast agent injection. Thus, adding a second or third postcontrast acquisition is helpful to capture this washout and to improve conspicuity of malignant lesions with persistent enhancement (eg, ductal carcinoma in situ, low-grade invasive cancers) in patients with low BPE levels (Fig 8).

Being able to capture washout can be relevant for distinguishing enhancing masses with benign-appearing morphologic features, where the main differential diagnosis is between rapidly growing, biologically aggressive invasive cancer and fibroadenoma. Biologically aggressive cancers will consistently exhibit strong angiogenic activity, with fast wash-in and

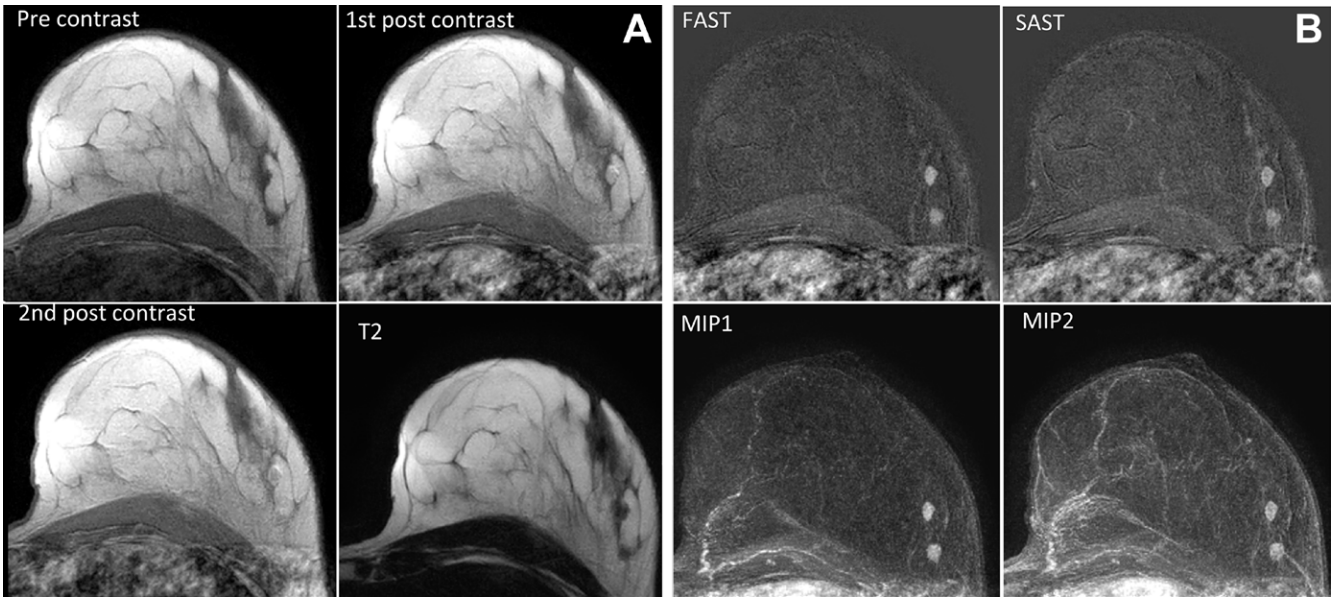

Figure 8: Abridged protocol subtype of abbreviated MRI, ie, first postcontrast subtracted (FAST) plus additional postcontrast acquisition plus T2-weighted imaging in a 58-year-old female patient with ductal carcinoma in situ and bifocal invasive breast cancer. **(A)** Abridged-protocol dynamic images consisting of one precontrast and two consecutive postcontrast acquisitions, taking 60 seconds each, and a T2-weighted acquisition, and **(B)** the respective postprocessed images consisting of FAST and second postcontrast subtracted (SAST) images and their respective maximum intensity projections (MIPs) show two enhancing masses with oval shape oriented along the breast's long axis, with smooth borders and homogeneous internal enhancement in the left breast. The second postcontrast acquisition helps detect washout indicative of malignancy and improves delineation of subtle ductal carcinoma in situ. Low signal intensity of enhancing masses in the T2-weighted image corroborates diagnosis of cancer versus fibroadenoma.

washout. While fast wash-in is often observed in fibroadenomas, washout is infrequent (Fig 8) (33).

Our clinical abridged protocol is based on FAST and adds a second postcontrast dynamic acquisition (ie, rapid abridged multiphase) and a high-spatial-resolution non–fat-suppressed T2-weighted acquisition (34), for a total acquisition time of 6 minutes (Fig 8).

To our knowledge, there is no evidence on which additional pulse sequence provides the best added value. Considering the equivalent diagnostic accuracies of all published short and abridged protocols compared with the respective full protocols discussed herein, this decision is likely related to personal preference and the image quality of a particular clinical practice. For example, UF MRI may not be readily obtained with older magnets or breast coils, or facilities may lack radiologists who can interpret DWI. Thus, beyond the perceived need to standardize procedures in clinical medicine, the choice of which additional pulse sequence, or sequences, to add should be based on each radiologist's preference, stability of achievable image quality, ease of performance in a clinical setting, and additional reading time.

This flexibility in imaging protocol was implemented in the multicenter study by Comstock et al (35) (ECOG-ACRIN Cancer Research Group study no. EA1141, hereafter called EA1141), which compared short-protocol abbreviated MRI with DBT. In that study, the inclusion of additional pulse sequences was left up to the individual participating site radiologist to decide. The only requirement was that the entire pulse sequence protocol should be less than 10 minutes. This stipulation should not be misunderstood as a proposed definition of abbreviated MRI.

Noncontrast Abbreviated MRI

The concept of noncontrast abbreviated MRI is to replace the functional information usually provided by DCE MRI with DWI using T2-weighted imaging to recover some structural information (36,37). The aim is to avoid the costs, logistic requirements, and possible adverse effects associated with the use of gadolinium-based contrast agents (GBCAs). Especially when breast MRI is used serially in mostly healthy individuals (ie, screening), the resulting high cumulative doses of GBCAs have raised concerns regarding possible retention and deposition of gadolinium. Although macrocyclic GBCAs have not been associated with such deposition (38), and despite the fact that high-relaxivity contrast agents will further reduce the injected GBCA dose (39) and artificial intelligence will further reduce the need for contrast agents (40), it is obvious that it is better to offer a screening test without intravenous injection.

The basis of breast cancer detection in DWI is that, due to the high cellularity of breast cancer, the mobility of free (interstitial) water molecules is reduced. The distance that free water molecules can travel per unit of time is called the apparent diffusion coefficient. Invasive cancers exhibit lower apparent diffusion coefficient values than normal tissue or benign lesions. Because this difference increases with increasing cellularity, and thus increasing biologic aggressiveness of cancers, DWI appears promising for screening for prognostically important breast cancer. In a current review of noncontrast MRI (not noncontrast abbreviated) for breast cancer screening using readers who were blinded to clinical history and contrast-enhanced images, sensitivities ranged 45%–94% and specificities ranged 79%–95% (41).

Table 1: Prospective Reader Studies Using FAST for Short-Protocol MRI

Study	Scan Time (min)		Type of Cohort	No. of Women (n = 1694)	MRI Studies (n = 2226)	Cancers (n = 32)	Results
	AB MRI	FDP MRI					
Kuhl et al, 2014 (7)	3	17	Screening women at average risk	443	606	11	Sensitivity, specificity, PPV, and NPV (nsd)
Harvey et al, 2016 (42)	4.5	23	Screening women at high risk	505	568	7	Cancer detection, FAST vs FDP; both 12.3 per 1000
Panigrahi et al, 2017 (43)	3	24	Screening women at high risk	746	1052	14	Sensitivity and specificity (nsd)

Note.—AB = abbreviated, FAST = first postcontrast subtracted, FDP = full diagnostic protocol, NPV = negative predictive value, nsd = not statistically significantly different, PPV = positive predictive value.

However, in view of the limited evidence on noncontrast protocols, this review article focuses on protocols that employ contrast-enhanced imaging.

Scientific Evidence

Diagnostic Accuracy of Abbreviated versus Full-Protocol MRI

The diagnostic accuracy of abbreviated MRI has been compared with full-protocol or multiparametric MRI mostly through so called "reader studies." In these reader studies, every patient underwent full or multiparametric MRI protocols, and the respective abbreviated protocol was then simulated in that readers were provided with only a defined fraction of the acquired images according to the respective authors' definition of an abbreviated protocol.

Reader studies are well suited to compare the diagnostic accuracies of abbreviated protocols with that of respective full or multiparametric protocols because they offer an intraindividual head-to-head comparison. In prospective reader studies, images were interpreted as part of clinical reading, before reviewing the respective full or multiparametric protocol, thus avoiding interpretation and selection bias. Therefore, prospective reader studies provide more valid results than retrospective reader studies.

At the time this article was written, three prospective (7,42,43) and 20 retrospective (18,28,30–32,44–58) reader studies have reported results obtained in 6198 patients. The three prospective reader studies used FAST MRI; most retrospective reader studies added additional comparisons with various subtypes of abridged protocols; and four reader studies used UF MRI. Meta-analyses have already been published that summarize the results of the individual studies (59–61). However, these meta-analyses did not distinguish between the different subtypes of abbreviated MRI. Tables 1–4 provide results of the individual studies according to subtype of abbreviated MRI.

Regarding sensitivity and cancer detection rates, each of the tested subtypes of abbreviated protocols, including short protocols (FAST and UF MRI), were equivalent to the respective full diagnostic protocols.

Regarding specificity, for all subtypes of abridged-protocol MRI, and for the UF subtype of short-protocol MRI, published results concordantly suggested either equivalent or even higher specificity compared with the respective full protocols. For FAST MRI, although three retrospective reader studies by Chen et al (47,50) and Naranjo et al (58) reported a significantly lower specificity, the majority (ie, 11 publications, notably including the three aforementioned prospective reader studies) reported an equivalent or higher specificity (7,42–44,46,48,51,53–55,57).

Altogether, based on the individual studies as well as published meta-analyses, abbreviated MRI offers the same diagnostic accuracy as full or multiparametric MRI protocols, and this is true for abbreviated MRI with short as well as with abridged protocols. Thus, it is incorrect to state that abbreviated protocols would reduce specificity compared with full-protocol MRI, an assumption seen in published cost-effectiveness analyses.

In view of the equivalent diagnostic accuracy of short and abridged protocols, the question becomes: "How are the additional pulse sequences that make up abridged protocols justified?" In our experience, the additional sequences are currently mainly needed to improve reader confidence when abbreviated MRI is used in clinical practice rather than in research settings. Research studies on abbreviated MRI have been reader studies, where the use of abbreviated MRI was only simulated. In such a virtual simulated research setting, the respective diagnoses will not have clinical consequences, and readers were necessarily aware of this. This is different when real decisions must be made based on abbreviated protocols alone.

However, the equivalent diagnostic accuracies of short-protocol compared with full-protocol or multiparametric MRI demonstrate that short protocols (FAST and possibly also UF MRI) do provide all diagnostic information needed for reliable detection and differential diagnosis of breast cancer. With increasing reader experience in interpreting short protocols, the confidence in short-protocol abbreviated MRI will grow, likely obviating the perceived need for the additional pulse sequences currently used in abridged-protocol abbreviated MRI.

Diagnostic Accuracy of UF versus FAST MRI

While reader studies are useful to compare the performance of abbreviated protocols with that of full or multiparametric protocols in the same patients, this is not true for the comparison of the different subtypes of short-protocol MRI, namely FAST and UF. This is because both FAST and UF MRI imply imaging before and immediately after contrast agent injection (ie, during the early postcontrast phase). For a fair head-to-head

Table 2: Retrospective Reader Studies Using FAST for Short- or Abridged-Protocol Abbreviated MRI

Study	Type of AB MRI	Scan Time (min)		Type of Cohort	No. of Women (n = 3380)	MRI Studies (n = 3515)	Cancers (n = 544)	Results
		AB MRI	FDP MRI					
Mango et al, 2015 (45)	SP: FAST	10–15	30–40	Enriched cohort: Patients with breast cancer	100	100	100	Across 4 independent readers, high sensitivity
Jain et al, 2016 (48)	SP: FAST	NA	NA	Screening women at high risk	591	591	9	Sensitivity and false-positive rate (nsd)
Chen et al, 2016 (50)	SP: FAST	NA	12.5	Screening women with dense breasts and negative mammogram	478	478	16	Sensitivity (nsd); specificity lower for FAST vs FDP; PPV, NPV, and AUC (nsd)
Petrillo et al, 2017 (51)	SP: FAST	3	17–20	Women undergoing MRI for screening, assessment, or staging	508	508	207	Accuracy, exactly equivalent at patient or lesion level
Seppala et al, 2018 (53)	SP: FAST	4.5	17	Enriched cohort: 23 with cancer 33 with benign lesions 44 without lesion	100	100	23	Pooled results across three readers; sensitivity, specificity, and accuracy (nsd)
Oldrini et al, 2018 (54)	SP: FAST	3	30–60	Enriched cohort: 30 BI-RADS 4–5 30 BI-RADS 3 30 BI-RADS 1–2	90	90	26	AUC (nsd), for both junior and senior readers
Dialani et al, 2019 (55)	SP: FAST	3	16	Screening women at high risk	259	259	7	FAST vs FDP, including prior MRI; sensitivity, 93% vs 100%; specificity, 91% vs 89%; no statistical analysis
Wahab et al, 2021 (56)	SP: FAST	10	40	Enriched cohort: Women at high risk with enhancing lesions	32	32	3	Patients underwent FAST first and, in case of any suspicious findings, underwent FDP; no cancer missed by AB MRI
Moraes et al, 2022 (57)	SP: FAST	3.5–5.5	14–27.5	Women undergoing MRI for screening, assessment, or staging	419	419	NA	Sensitivity, specificity, and PPV (nsd)
Heacock et al, 2016 (46)	SP: FAST AP: FAST + T2	4 12	35	Enriched cohort: Patients with breast cancer	107	107	107	Sensitivity and specificity (nsd)
Chen et al, 2017 (47)	SP: FAST AP: FAST + DWI	2 2.5	32	Screening women with dense breasts and negative mammograms	356	356	14	Sensitivity and NPV (nsd); specificity, lower for FAST, with no difference between AP vs FDP
Naranjo et al, 2022 (58)	SP: FAST AP: FAST + T2	4 8	16	Screening women at high risk (*BRCA* mutation carriers)	292	427	20	Sensitivity, NPV, and accuracy (nsd); specificity and PPV, significantly lower for FAST, equivalent for AP and FDP

Table 2 *(continues)*

comparison this requires two separate examinations, one with UF MRI and then, on a separate day after contrast agent washout, one with FAST MRI (or vice versa). However, all published studies on the comparison of UF with FAST MRI, so far, have been reader studies. In each of these reader studies, UF and FAST sequences were obtained within one examination, with UF MRI always obtained first, followed by DCE (Fig 6C). Thus, the first postcontrast acquisitions (ie, the FAST

Table 2 *(continued)*: Retrospective Reader Studies Using FAST for Short- or Abridged-Protocol Abbreviated MRI

Study	Type of AB MRI	Scan Time (min) AB MRI	Scan Time (min) FDP MRI	Type of Cohort	No. of Women (n = 3380)	MRI Studies (n = 3515)	Cancers (n = 544)	Results
Grimm et al, 2015 (44)	APs only; AP1: FAST + T2 AP2: RAMP + T2	 5 7	20	Enriched cohort: 12 with cancer 12 with benign lesions 24 without lesion	48	48	12	Sensitivity and specificity (nsd)

Note.—AB = abbreviated, AP = abridged protocol, AUC = area under the receiver operating characteristic curve, BI-RADS = Breast Imaging Reporting and Data System, DWI = diffusion-weighted imaging, FAST = first postcontrast subtracted, FDP = full diagnostic protocol, NA = not available, NPV = negative predictive value, nsd = not statistically significantly different, PPV = positive predictive value, RAMP = rapid abridged multiphase, SP = short protocol, T2 = T2-weighted imaging.

Table 3: Retrospective Reader Studies Using UF MRI for Short- or Abridged-Protocol Abbreviated MRI

Study	Type of AB MRI	Scan Time (min) AB MRI	Scan Time (min) FDP MRI	Type of Cohort	No. of Women (n = 479)	MRI Studies (n = 479)	Cancers (n = 220)	Results
Machida et al, 2016 (32)	SP: VIBE before contrast and UF for 80 sec after contrast agent injection	NA	NA	Enriched cohort: 28 with cancer 12 with benign lesions 48 without lesion	88	88	28	Sensitivity, specificity, and PPV (nsd)
van Zelst et al, 2018 (29)	SP: UF	1.6	13	Enriched cohort: 31 with cancer 54 with benign lesions 116 without lesion	201	201	31	UF vs FDP with delayed postcontrast phase, pooled 7 readers; sensitivity (nsd); specificity, higher for UF than for FDP with delayed FAST; PPV and AUC (nsd)
Oldrini et al, 2017 (28)	SP: UF AP1: delayed FAST + T2 AP2: UF + delayed FAST + T2	3 4.5 4.5	11.5	Enriched cohort: 58 with cancer 48 with benign lesions	70	70	58	Delayed FAST vs AP1/2 vs UF vs UF + AP vs FDP (nsd); specificity (nsd) for all approaches
Milon et al, 2019 (30)	AP1: delayed FAST + T2 AP2: UF + delayed FAST + T2	8 10	14	Enriched cohort: 103 with cancer 69 with benign lesions 7 with borderline lesions	120	120	103	AP1 vs AP2 vs FDP (without UF); sensitivity (nsd); specificity, significantly higher for UF vs delayed FAST

Note.—AB = abbreviated, AP = abridged protocol, AUC = area under the receiver operating characteristic curve, FAST = first postcontrast subtracted, FDP = full diagnostic protocol, NA = not available, nsd = not statistically significantly different, PPV = positive predictive value, RAMP = rapid abridged multiphase, SP = short protocol, T2 = T2-weighted imaging, UF = ultrafast, VIBE = volumetric interpolated breath-hold examination.

images of the respective DCE protocols) were delayed by the time needed to complete the UF sequence, which is not in agreement with the concept of FAST MRI. Thus, while UF imaging did cover the early postcontrast phase, it was consistently missed by the respective conventional DCE protocol, so that a true "first postcontrast subtracted" (FAST) image had, de facto, not been acquired. This will explain, at least in part, the specificity advantage observed for UF MRI in comparison with what authors called "FAST" in these reader studies. Thus, more research on prospective clinical trials is needed to further clarify the respective advantages and downsides of both methods.

Table 4: Retrospective Reader Studies Using Other Forms of Abridged Protocols

Study	Type of AB MRI	Scan Time (min)		Type of Cohort	No. of Women (n = 645)	MRI Studies (n = 645)	Cancers (n = 200)	Results
		AB MRI	FDP MRI					
Moschetta et al, 2016 (49)	AP: precontrast and third postcontrast + T2 + STIR	10	16	Women undergoing MRI for screening, assessment, or staging	470	470	75	Sensitivity, specificity, PPV, and NPV (nsd)
Romeo et al, 2017 (52)	AP: dynamic series over 5 min	7	15	Enriched cohort: Women with enhancing lesions	98	98	64	Sensitivity, specificity, PPV, and NPV (nsd)
Choudhery et al, 2019 (18)	AP: RAMP	4.5	22	Women undergoing MRI for screening, assessment, or staging	77	77	61	Equivalent time course pattern for RAMP vs DCE MRI; AUC (nsd)

Note.—AB = abbreviated, AP = abridged protocol, AUC = area under the receiver operating characteristic curve, DCE = dynamic contrast-enhanced, FDP = full diagnostic protocol, NPV = negative predictive value, nsd = not statistically significantly different, PPV = positive predictive value, RAMP = rapid abridged multiphase, STIR = short tau inversion recovery, T2 = T2-weighted imaging.

Clinical Performance of Abbreviated MRI

A clinical trial in this context is defined as a report on the clinical use of abbreviated MRI as a definitive examination. Trial participants underwent abbreviated MRI only (unlike in reader studies, where all had undergone full or multiparametric MRI protocols). Accordingly, further patient management had to be determined based on the results of the abbreviated protocol alone. Every clinical trial published so far has employed abridged-protocol rather than short-protocol abbreviated MRI. The most frequently used abridged-protocol subtype was the combination of FAST or rapid abridged multiphase (RAMP) with T2-weighted imaging.

At the time the current article was written, 13 original articles that include 9486 patients have been published to determine the clinical performance of abbreviated MRI. Applications included screening, surveillance after breast-conserving surgery for breast cancer, and diagnostic assessment (35,62–73).

Screening.—Two retrospective single-center and one prospective multicenter study (EA1141) have been published, including 3894 patients with 74 screen-detected breast cancers (Table 5) (35,70,71).

The EA1141 study investigated invasive and overall cancer detection using abbreviated breast MRI compared with DBT performed in the same 1444 participants with mostly intermediately dense breasts. At the time of the first EA1141 screening round, 77% of participants had a breast density categorized as American College of Radiology Breast Imaging Reporting and Data System C (heterogeneously dense), 15% had D (extremely dense), and the remaining 9% had lower densities. Abbreviated MRI and DBT studies in the same participants were read independently of each other to investigate the use of abbreviated MRI as a standalone screening tool rather than a supplement (35).

The EA1141 study demonstrated 2.45-fold higher cancer detection using abbreviated MRI (15.2 per 1000 at prevalence screening) compared with DBT (6.2 per 1000). This is in good agreement with the cancer detection rate (16.5 per 1000) observed in the DENSE (Dense Tissue and Early Breast Neoplasm Screening) trial, where full-protocol MRI was used in women with extremely dense breasts. Although EA1141 does not enable a comparison with full-protocol MRI, the results suggest that, regarding cancer detection, there is little room for improvement, with a sensitivity of 100% (17 of 17) for invasive cancer and 95.7% (22 of 23) for overall cancer detection. The specificity of abbreviated MRI (87%) was significantly lower than that of DBT (97%). The key question is whether full-protocol MRI would have offered a higher specificity. Although the EA1141 study design does not allow us to answer this question, the specificity observed in EA1141 meets the Breast Imaging Reporting and Data System performance benchmarks established for full-protocol MRI (74). Most EA1141 sites were in private or community practice settings; the specificity reported in the EA1141 study compares favorably with that of full-protocol MRI published for U.S. community practices (75). Therefore, the performance of abbreviated MRI within EA1141 is likely representative of the clinical performance of full-protocol MRI in the United States.

Surveillance after breast conservation surgery.—One prospective and seven retrospective clinical studies that included 5348 patients investigated the surveillance of patients after breast cancer (Table 6) (62–69). Recurrent ipsilateral or contralateral cancer was diagnosed in 106 patients, for an average cancer detection rate of 19.7 per 1000. Two articles compared the clinical performance of abbreviated MRI with a matched cohort undergoing full-protocol MRI (63,69). Both observed a higher specificity and positive predictive value for abbreviated MRI compared with full-protocol

Table 5: Evidence on the Use of Abbreviated MRI for Screening

Study	Study Design	Type of AB MRI	Scan Time (min)	Type of Cohort	No. of Women (n = 3894)	MRI Studies (n = 4956)	Cancers (n = 74)	Results
Comstock et al, 2020 (35)	Prospective, multicenter	AP: variable (<10 min)	8.3 (mean)	Screening of women at average risk with ACR BI-RADS c or d breast composition	1444	1444	23	AB MRI vs DBT (prevalence screening): CDR, 15.2 vs 6.2 per 1000 (significant); sensitivity, 96% vs 39% (significant); specificity, 87% vs 97% (significant); PPV, 20% vs 31% (nsd)
Weinstein et al, 2020 (70)	Retrospective, single center	AP: FAST + T2	NA	Screening of women at average risk with dense breasts	475	475	13	AB MRI (prevalence screening): CDR, 27.4 per 1000; PPV, 31% (12/39)
Kwon et al, 2021 (71)	Retrospective, single center	AP: RAMP + T2	10	High to intermediate risk screening	1975	3037	38	AB MRI: 29 of 38 cancers identified by AB MRI, 9 missed by AB MRI, 7 of 9 identified by DM and/or US; 2 interval cancers missed by all 3 methods; interval cancer rate, 0.66 per 1000; CDR, 8.9 per 1000; AB MRI PPV and sensitivity increased from year 1 to year 2 to year 3

Note.—AB = abbreviated, ACR = American College of Radiology, AP = abridged protocol, BI-RADS = Breast Imaging Reporting and Data System, CDR = cancer detection rate, DBT = digital breast tomosynthesis, DM = digital mammography, FAST = first postcontrast subtracted, NA = not available, nsd = not statistically significantly different, PPV = positive predictive value, RAMP = rapid abridged multiphase, T2 = T2-weighted imaging.

MRI in the respective control cohort. Where the diagnostic performance of abbreviated MRI was compared with conventional imaging, a significantly higher recurrent cancer detection rate and a higher specificity and positive predictive value were observed for abbreviated MRI than for mammography or DBT, especially when US was added to mammography.

Diagnostic assessment.—There is a current paucity of data on the use of abbreviated MRI for diagnostic assessment of mammographic or US findings, and we suggest that in such situations, full protocols should be given priority. Gweon et al (72) prospectively used abridged-protocol MRI (FAST plus T2-weighted MRI) in 80 patients for workup of mammographic microcalcifications categorized as Breast Imaging Reporting and Data System category 4. Results were in perfect concordance with those published in a prior study with full-protocol MRI (76), suggesting equivalent usefulness for this purpose.

In a retrospective reader study, Shiraishi et al (73) compared abbreviated with full-protocol MRI for delineating the extent of disease in 164 patients with pure ductal carcinoma in situ (DCIS). The correlation between predicted and histopathologically confirmed DCIS size was similar for both protocols. However, whereas underestimation of extent was more frequently observed with FAST MRI, overestimation was more frequently seen with full-protocol MRI. This is explainable due to slow persistent enhancement of DCIS. The study also demonstrates that, although the complete extent of DCIS may be better appreciated in later postcontrast phases as long as there is no strong BPE, DCIS is reliably detectable already with early postcontrast imaging.

Operational Issues with Implementing Abbreviated MRI

Abbreviated MRI, in particular FAST MRI, was introduced to reduce complexity and costs so that breast MRI would be suitable for mass screening. Indeed, FAST MRI complies with important prerequisites of population screening in that it is fast and relatively easy to acquire and read. In our proof-of-concept study that included 443 women undergoing 606 screening MRI examinations (7), the time to acquire FAST images was 3 minutes, which compares favorably with the time to complete a bilateral two-view mammographic examination. The average time

Table 6: Evidence on the Use of Abbreviated MRI for Follow-up of Patients with Personal History of Breast Cancer

Study	Study Design	Type of AB MRI	Scan Time (min)	No. of Women (n = 5348)	MRI Studies (n = 6838)	Cancers (n = 106)	Results
Choi et al, 2018 (62)	Prospective, clinical	AP: FAST + T2	8.5	725	799	12	AB MRI vs DM + US: CDR, 15.0 vs 6.2 per 1000; sensitivity, 100% (12/12) vs 50% (6/12); AB MRI: specificity, 89% (702/787); PPV1, 12.4% (12/97)
Park et al, 2020 (63)	Retrospective, clinical, with matched pairs	AP: RAMP + T2	10–11	656, both AB and FDP	656, both AB and FDP	10 AB, with 5 FDP	AB MRI vs FDP: sensitivity, specificity, PPV, NPV, and AUC (nsd)
An et al, 2020 (64)	Retrospective, clinical	AP: FAST + T2	8	763	1880	21	AB MRI vs DM + US: CDR, 19 vs 10 per 1000; sensitivity, 95% vs 48%; PPV, 57% vs 38%
Kwon et al, 2020 (65)	Retrospective, clinical	AP: RAMP + T2	10	973	1043	14	AB MRI: CDR, 9.6 per 1000; sensitivity, 97% (11/14); specificity, 98%; PPV2, 55% (11/20)
Baek et al, 2021 (66)	Retrospective, clinical	AP: RAMP + T2	10	710	939	15	AB MRI vs DM vs US: CDR, 11.7 vs 3.2 vs 4.3 per 1000; sensitivity, 73% vs 19% vs 25% (significant); AUC, 0.829 vs 0.592 vs 0.616 (significant)
Kim et al, 2021 (67)	Retrospective, clinical*	AP: FAST + T2	8.3	324	324	8	AB MRI vs DM vs US vs DM + US: CDR, 25 per 1000 vs 9 per 1000 vs 12 per 1000 vs 15 per 1000 (significant); sensitivity, 100% vs 37.5% vs 50% vs 62.5%; specificity, 97.8% vs 99.7% vs 98.4% vs 98.1%; PPV, 53.3% vs 75.0% vs 44.4% vs 45.5%
Kim et al, 2022 (68)	Retrospective, clinical	AP: FAST + T2	8.3	471	471	11	AB MRI vs DBT: CDR, 23.4 per 1000 vs 12.7 per 1000 (significant); sensitivity, 100% vs 54.6% (significant); specificity, 96.5% vs 97.6% (nsd); PPV, 40.7% vs 35.3%; AUC, 0.983 vs 0.761 (significant)
Kim et al, 2022 (69)	Retrospective, clinical, matched pairs with propensity score alignment	AP: FAST + T2	8–9	726, both AB and FDP	726, both AB and FDP	15 AB, with 13 FDP	AB MRI vs FDP: CDR, 21 per 1000 (15/726) vs 12 per 1000 (9/726) (nsd); sensitivity, 100% (15/15) vs 69% (9/13) (nsd); specificity, 93% (660/711) vs 86% (612/713) (significant); PPV3, 61% (14/23) vs 41% (9/22) (nsd)

Note.—AB = abbreviated, AP = abridged protocol, AUC = area under the receiver operating characteristic curve, CDR = cancer detection rate, DM = digital mammography, FAST = first postcontrast subtracted, FDP = full diagnostic protocol, NPV = negative predictive value, nsd = not statistically significantly different, PPV = positive predictive value, RAMP = rapid abridged multiphase, T2 = T2-weighted imaging.
* Patients with acellular dermal matrix reconstruction.

to identify healthy women (absence of enhancement based on a negative maximum intensity projection) was 2.8 seconds (range, 1–6 seconds) (7). Being able to quickly identify negative cases is especially relevant in screening settings, where the majority of studies will be negative. This is an advantage of abbreviated MRI compared with low-contrast methods, such as US or mammography, where establishing the presence or absence of disease requires approximately the same amount of time.

Even when the individual FAST images plus, possibly, the respective nonsubtracted source images had to be reviewed, the average reading time was only 28 seconds (range, 20–48 seconds); Chen et al (47) and Mango et al (45) reported similar reading times. Thus, the time needed to establish a final diagnosis based on a FAST image is equivalent to the time needed for batch reading of screening mammograms (77), and is much faster than reading DBT or US studies (78,79).

Due to short acquisition and reading times and the relatively basic MRI technology it requires, using FAST MRI for population-wide screening appears conceivable. A key requirement to put this into practice, however, is the availability of

dedicated breast MRI systems optimized for such high-volume high-throughput screening. With the current all-purpose MRI machines, the time it takes to help women into a prone position and to position the breast in the breast coil all add to magnet time. Once examination time becomes shorter than the time needed for setup, the latter will dominate (limit) the number of screening examinations completed per hour of magnet time (80). The full potential of abbreviated MRI to reduce costs associated with MRI screening, thus its cost-effectiveness, will only be assessable when optimized dedicated MRI systems are available.

Of similar importance is the fact that the current clinical setting for abbreviated MRI screening is different from the intended use of FAST MRI, which was proposed to support population-wide screening. Within organized screening programs, the key is to balance cancer detection with practicability and costs. Yet, in its current use in the setting of individualized screening, the expectation of patients is to maximize sensitivity and ensure the earliest possible diagnosis.

Accordingly, with the technological equipment currently available and with its current use for individualized screening and, even more so, for diagnostic applications (ie, staging), it seems pointless to push the reduction of image acquisition time to an extent as that proposed by FAST MRI. Rather, it seems sensible to invest somewhat more time in image acquisition. This is what abridged protocols do.

Future Directions

In the future, deep learning will help interpret abbreviated MRI (81). With such artificial intelligence–based analysis, short-protocol abbreviated MRI (UF or FAST) will likely be the preferred screening method. By fully exploiting the concept of UF MRI, it may be sufficient to acquire only the first couple seconds after contrast agent injection to capture the onset of enhancement, with artificial intelligence reconstructing the undersampled morphologic image information (4).

Abbreviated MRI was introduced to increase access to breast MRI. Given that full-protocol MRI is cost-effective in individuals at high risk and in those with extremely dense breasts (82,83,84), research on abbreviated MRI screening should focus on applications beyond this group. The frequently atypical imaging presentation, especially of *BRCA1*-associated breast cancer (85), is another reason to avoid short-protocol abbreviated MRI in women at high risk. Therefore, for those at high risk, we recommend using full protocols for the respective first screening rounds and reserve abridged protocols for follow-up rounds.

Future target populations are individuals at risk for mammographic screening failure, such as those identified by artificial intelligence–based analyses of mammograms and/or of BPE patterns on MRI scans (86–89). This should include women aged 40–50 years who are currently excluded from screening, despite the fact that breast cancers in this cohort cause more life-years lost than those diagnosed in current screening cohorts (90,91).

Beyond aspects of cost-effectiveness, abbreviated MRI will be key to increasing patients' overall acceptance of MRI as a screening tool. Initial evidence suggests that 75% of 200 women preferred undergoing abbreviated MRI over mammography (92,93).

Conclusion

In conclusion, abbreviated breast MRI is a mature method that offers similar diagnostic accuracy as full-protocol MRI. This was true for all tested clinical applications. Eventually, its use will improve access to the most powerful breast cancer imaging and screening tool of contemporary medicine—MRI.

Disclosures of conflicts of interest: C.K.K. Payment or honoraria for lectures from Guerbet and Bayer.

References

1. van Beek EJR, Kuhl C, Anzai Y, et al. Value of MRI in medicine: More than just another test? J Magn Reson Imaging 2019;49(7):e14–e25.
2. Pruessmann KP, Weiger M, Scheidegger MB, Boesiger P. SENSE: sensitivity encoding for fast MRI. Magn Reson Med 1999;42(5):952–962.
3. Lustig M, Donoho D, Pauly JM. Sparse MRI: The application of compressed sensing for rapid MR imaging. Magn Reson Med 2007;58(6):1182–1195.
4. Lin DJ, Johnson PM, Knoll F, Lui YW. Artificial Intelligence for MR Image Reconstruction: An Overview for Clinicians. J Magn Reson Imaging 2021;53(4):1015–1028.
5. Wessman BV, Moriarity AK, Ametlli V, Kastan DJ. Reducing barriers to timely MR imaging scheduling. RadioGraphics 2014;34(7):2064–2070.
6. Edelstein WA, Mahesh M, Carrino JA. MRI: time is dose--and money and versatility. J Am Coll Radiol 2010;7(8):650–652.
7. Kuhl CK, Schrading S, Strobel K, Schild HH, Hilgers RD, Bieling HB. Abbreviated breast magnetic resonance imaging (MRI): first postcontrast subtracted images and maximum-intensity projection-a novel approach to breast cancer screening with MRI. J Clin Oncol 2014;32(22):2304–2310.
8. Kuhl CK, Bruhn R, Krämer N, Nebelung S, Heidenreich A, Schrading S. Abbreviated Biparametric Prostate MR Imaging in Men with Elevated Prostate-specific Antigen. Radiology 2017;285(2):493–505.
9. Kang Z, Min X, Weinreb J, Li Q, Feng Z, Wang L. Abbreviated Biparametric Versus Standard Multiparametric MRI for Diagnosis of Prostate Cancer: A Systematic Review and Meta-Analysis. AJR Am J Roentgenol 2019;212(2):357–365.
10. Gupta P, Soundararajan R, Patel A, Kumar-M P, Sharma V, Kalra N. Abbreviated MRI for hepatocellular carcinoma screening: A systematic review and meta-analysis. J Hepatol 2021;75(1):108–119.
11. Lee SL, Shin YR, Kim K. The added value of pelvic surveillance by MRI during postoperative follow-up of rectal cancer, with a focus on abbreviated MRI. Eur Radiol 2020;30(6):3113–3124.
12. Kang HJ, Lee DH, Lee JM, et al. Clinical Feasibility of Abbreviated Magnetic Resonance With Breath-Hold 3-Dimensional Magnetic Resonance Cholangiopancreatography for Surveillance of Pancreatic Intraductal Papillary Mucinous Neoplasm. Invest Radiol 2020;55(5):262–269.
13. Ross AB, Chan BY, Yi PH, Repplinger MD, Vanness DJ, Lee KS. Diagnostic accuracy of an abbreviated MRI protocol for detecting radiographically occult hip and pelvis fractures in the elderly. Skeletal Radiol 2019;48(1):103–108.
14. Lumba-Brown A, Lee MO, Brown I, et al. Emergency department implementation of abbreviated magnetic resonance imaging for pediatric traumatic brain injury. J Am Coll Emerg Physicians Open 2020;1(5):994–999.
15. Mann RM, Kuhl CK, Moy L. Contrast-enhanced MRI for breast cancer screening. J Magn Reson Imaging 2019;50(2):377–390.
16. Breast Imaging Reporting and Data System (BI-RADS) 5th Edition, Atlas Reporting System for Breast MRI. American College of Radiology. https://www.acr.org/-/media/ACR/Files/RADS/BI-RADS/MRI-Reporting.pdf. Published 2013. Accessed February 2, 2023.
17. Kaiser WA, Zeitler E. MR imaging of the breast: fast imaging sequences with and without Gd-DTPA. Preliminary observations. Radiology 1989;170(3 Pt 1):681–686.
18. Choudhery S, Chou SS, Chang K, Kalpathy-Cramer J, Lehman CD. Kinetic Analysis of Lesions Identified on a Rapid Abridged Multiphase (RAMP) Breast MRI Protocol. Acad Radiol 2019;27(5):672–681.
19. Mann RM, Mus RD, van Zelst J, Geppert C, Karssemeijer N, Platel B. A novel approach to contrast-enhanced breast magnetic resonance imaging for screening: high-resolution ultrafast dynamic imaging. Invest Radiol 2014;49(9):579–585.

20. Gao Y, Heller SL. Abbreviated and Ultrafast Breast MRI in Clinical Practice. RadioGraphics 2020;40(6):1507–1527.
21. Mann RM, Kuhl CK, Kinkel K, Boetes C. Breast MRI: guidelines from the European Society of Breast Imaging. Eur Radiol 2008;18(7):1307–1318.
22. Kuhl C. The current status of breast MR imaging. Part I. Choice of technique, image interpretation, diagnostic accuracy, and transfer to clinical practice. Radiology 2007;244(2):356–378.
23. Herrmann KH, Baltzer PA, Dietzel M, et al. Resolving arterial phase and temporal enhancement characteristics in DCE MRM at high spatial resolution with TWIST acquisition. J Magn Reson Imaging 2011;34(4):973–982.
24. van Vaals JJ, Brummer ME, Dixon WT, et al. "Keyhole" method for accelerating imaging of contrast agent uptake. J Magn Reson Imaging 1993;3 (4):671–675.
25. Mus RD, Borelli C, Bult P, et al. Time to enhancement derived from ultrafast breast MRI as a novel parameter to discriminate benign from malignant breast lesions. Eur J Radiol 2017;89:90–96.
26. Ramtohul T, Tescher C, Vaflard P, et al. Prospective Evaluation of Ultrafast Breast MRI for Predicting Pathologic Response after Neoadjuvant Therapies. Radiology 2022;305(3):565–574.
27. Kataoka M, Honda M, Ohashi A, et al. Ultrafast Dynamic Contrast-enhanced MRI of the Breast: How Is It Used? Magn Reson Med Sci 2022;21(1):83–94.
28. Oldrini G, Fedida B, Poujol J, et al. Abbreviated breast magnetic resonance protocol: Value of high-resolution temporal dynamic sequence to improve lesion characterization. Eur J Radiol 2017;95:177–185.
29. van Zelst JCM, Vreemann S, Witt HJ, et al. Multireader Study on the Diagnostic Accuracy of Ultrafast Breast Magnetic Resonance Imaging for Breast Cancer Screening. Invest Radiol 2018;53(10):579–586.
30. Milon A, Vande Perre S, Poujol J, et al. Abbreviated breast MRI combining FAST protocol and high temporal resolution (HTR) dynamic contrast enhanced (DCE) sequence. Eur J Radiol 2019;117:199–208.
31. Miceli R, Gao Y, Qian K, Heller SL. Predicting Upgrade of Ductal Carcinoma In Situ to Invasive Breast Cancer at Surgery With Ultrafast Imaging. AJR Am J Roentgenol 2023;221(1):34–43.
32. Machida Y, Shimauchi A, Kanemaki Y, Igarashi T, Harada M, Fukuma E. Feasibility and potential limitations of abbreviated breast MRI: an observer study using an enriched cohort. Breast Cancer 2016;24(3):411–419.
33. Kuhl CK, Mielcareck P, Klaschik S, et al. Dynamic breast MR imaging: are signal intensity time course data useful for differential diagnosis of enhancing lesions? Radiology 1999;211(1):101–110.
34. Kuhl CK, Klaschik S, Mielcarek P, Gieseke J, Wardelmann E, Schild HH. Do T2-weighted pulse sequences help with the differential diagnosis of enhancing lesions in dynamic breast MRI? J Magn Reson Imaging 1999;9(2):187–196.
35. Comstock CE, Gatsonis C, Newstead GM, et al. Comparison of Abbreviated Breast MRI vs Digital Breast Tomosynthesis for Breast Cancer Detection Among Women With Dense Breasts Undergoing Screening. JAMA 2020;323(8):746–756.
36. Bickelhaupt S, Laun FB, Tesdorff J, et al. Fast and Noninvasive Characterization of Suspicious Lesions Detected at Breast Cancer X-Ray Screening: Capability of Diffusion-weighted MR Imaging with MIPs. Radiology 2016;278(3):689–697.
37. Yamada T, Kanemaki Y, Okamoto S, Nakajima Y. Comparison of detectability of breast cancer by abbreviated breast MRI based on diffusion-weighted images and postcontrast MRI. Jpn J Radiol 2018;36(5):331–339.
38. Bennani-Baiti B, Krug B, Giese D, et al. Evaluation of 3.0-T MRI Brain Signal after Exposure to Gadoterate Meglumine in Women with High Breast Cancer Risk and Screening Breast MRI. Radiology 2019;293(3):523–530.
39. Kuhl C, Csőszi T, Piskorski W, Miszalski T, Lee JM, Otto PM. Efficacy and Safety of Half-Dose Gadopiclenol versus Full-Dose Gadobutrol for Contrast-enhanced Body MRI. Radiology 2023;308(1):e222612.
40. Müller-Franzes G, Huck L, Tayebi Arasteh S, et al. Using Machine Learning to Reduce the Need for Contrast Agents in Breast MRI through Synthetic Images. Radiology 2023;307(3):e222211.
41. Amornsiripanitch N, Bickelhaupt S, Shin HJ, et al. Diffusion-weighted MRI for Unenhanced Breast Cancer Screening. Radiology 2019;293(3):504–520.
42. Harvey SC, Di Carlo PA, Lee B, Obadina E, Sippo D, Mullen L. An Abbreviated Protocol for High-Risk Screening Breast MRI Saves Time and Resources. J Am Coll Radiol 2016;13(4):374–380.
43. Panigrahi B, Mullen L, Falomo E, Panigrahi B, Harvey S. An Abbreviated Protocol for High-risk Screening Breast Magnetic Resonance Imaging: Impact on Performance Metrics and BI-RADS Assessment. Acad Radiol 2017;24(9):1132–1138.
44. Grimm LJ, Soo MS, Yoon S, Kim C, Ghate SV, Johnson KS. Abbreviated screening protocol for breast MRI: a feasibility study. Acad Radiol 2015;22(9):1157–1162.
45. Mango VL, Morris EA, David Dershaw D, et al. Abbreviated protocol for breast MRI: are multiple sequences needed for cancer detection? Eur J Radiol 2015;84(1):65–70.
46. Heacock L, Melsaether AN, Heller SL, et al. Evaluation of a known breast cancer using an abbreviated breast MRI protocol: Correlation of imaging characteristics and pathology with lesion detection and conspicuity. Eur J Radiol 2016;85(4):815–823.
47. Chen SQ, Huang M, Shen YY, Liu CL, Xu CX. Abbreviated MRI Protocols for Detecting Breast Cancer in Women with Dense Breasts. Korean J Radiol 2017;18(3):470–475.
48. Jain M, Jain A, Hyzy MD, Werth G. FAST MRI breast screening revisited. J Med Imaging Radiat Oncol 2016;61(1):24–28.
49. Moschetta M, Telegrafo M, Rella L, Stabile Ianora AA, Angelelli G. Abbreviated Combined MR Protocol: A New Faster Strategy for Characterizing Breast Lesions. Clin Breast Cancer 2016;16(3):207–211.
50. Chen SQ, Huang M, Shen YY, Liu CL, Xu CX. Application of Abbreviated Protocol of Magnetic Resonance Imaging for Breast Cancer Screening in Dense Breast Tissue. Acad Radiol 2016;24(3):316–320.
51. Petrillo A, Fusco R, Sansone M, et al. Abbreviated breast dynamic contrast-enhanced MR imaging for lesion detection and characterization: the experience of an Italian oncologic center. Breast Cancer Res Treat 2017;164(2):401–410.
52. Romeo V, Cuocolo R, Liuzzi R, et al. Preliminary Results of a Simplified Breast MRI Protocol to Characterize Breast Lesions: Comparison with a Full Diagnostic Protocol and a Review of the Current Literature. Acad Radiol 2017;24(11):1387–1394.
53. Seppala N, Fallah Rastegar R, Richmond L, et al. Rapid MRI of the breast in evaluating lesions discovered on screening. Breast J 2018;24(6):986–991.
54. Oldrini G, Derraz I, Salleron J, Marchal F, Henrot P. Impact of an abbreviated protocol for breast MRI in diagnostic accuracy. Diagn Interv Radiol 2018;24(1):12–16.
55. Dialani V, Tseng I, Slanetz PJ, et al. Potential role of abbreviated MRI for breast cancer screening in an academic medical center. Breast J 2019;25(4):604–611.
56. Wahab RA, Albasha H, Martin J, et al. Characterization of common breast MRI abnormalities: comparison between abbreviated and full MRI protocols. Clin Imaging 2021;79:125–132.
57. Moraes MO, Forte GC, Guimarães ADSG, et al. Breast MRI: Simplifying Protocol and BI-RADS Categories. Clin Breast Cancer 2022;22(5):e615–e622.
58. Naranjo ID, Sogani J, Saccarelli C, et al. MRI Screening of *BRCA* Mutation Carriers: Comparison of Standard Protocol and Abbreviated Protocols With and Without T2-Weighted Images. AJR Am J Roentgenol 2022;218(5):810–820.
59. Zhou B, He W, Kaur J, Cai Q, Bhat A, Liu Q. Meta-Analysis of Abbreviated MRI Scanning Reveals a High Specificity and Sensitivity in Detecting Breast Cancer. Clin Exp Obstet Gynecol 2023;50(6):115.
60. Geach R, Jones LI, Harding SA, et al; FAST MRI Study Group. The potential utility of abbreviated breast MRI (FAST MRI) as a tool for breast cancer screening: a systematic review and meta-analysis. Clin Radiol 2021;76(2):154.e11–154.e22.
61. Baxter GC, Selamoglu A, Mackay JW, Bond S, Gray E, Gilbert FJ. A meta-analysis comparing the diagnostic performance of abbreviated MRI and a full diagnostic protocol in breast cancer. Clin Radiol 2021;76(2):154.e23–154.e32.
62. Choi BH, Choi N, Kim MY, Yang JH, Yoo YB, Jung HK. Usefulness of abbreviated breast MRI screening for women with a history of breast cancer surgery. Breast Cancer Res Treat 2018;167(2):495–502. [Published correction appears in Breast Cancer Res Treat 2018;167(2):503.]
63. Park KW, Han SB, Han BK, et al. MRI surveillance for women with a personal history of breast cancer: comparison between abbreviated and full diagnostic protocol. Br J Radiol 2020;93(1106):20190733.
64. An YY, Kim SH, Kang BJ, Suh YJ, Jeon YW. Feasibility of abbreviated magnetic resonance imaging (AB-MRI) screening in women with a personal history (PH) of breast cancer. PLoS One 2020;15(3):e0230347.
65. Kwon MR, Ko EY, Han BK, Ko ES, Choi JS, Park KW. Diagnostic performance of abbreviated breast MRI for screening of women with previously treated breast cancer. Medicine (Baltimore) 2020;99(16):e19676.
66. Baek SJ, Ko KH, Jung HK, Park AY, Koh J. Comparison of Abbreviated MRI with Mammography and Ultrasound in Women with a Personal History of Breast Cancer. Acad Radiol 2021;29(Suppl 1):S19–S25.
67. Kim MY, Suh YJ, An YY. Imaging surveillance for the detection of ipsilateral local tumor recurrence in patients who underwent oncoplastic breast-conserving surgery with acellular dermal matrix: abbreviated

MRI versus conventional mammography and ultrasonography. World J Surg Oncol 2021;19(1):290.
68. Kim MY, Suh YJ, An YY. Comparison of Abbreviated Breast MRI vs Digital Breast Tomosynthesis for Breast Cancer Detection among Women with a History of Breast Cancer. Acad Radiol 2022;29(10):1458–1465.
69. Kim SY, Cho N, Hong H, et al. Abbreviated Screening MRI for Women with a History of Breast Cancer: Comparison with Full-Protocol Breast MRI. Radiology 2022;305(1):36–45.
70. Weinstein SP, Korhonen K, Cirelli C, et al. Abbreviated Breast Magnetic Resonance Imaging for Supplemental Screening of Women With Dense Breasts and Average Risk. J Clin Oncol 2020;38(33):3874–3882.
71. Kwon MR, Choi JS, Won H, et al. Breast Cancer Screening with Abbreviated Breast MRI: 3-year Outcome Analysis. Radiology 2021;299(1):73–83.
72. Gweon HM, Eun NL, Youk JH, et al. Added value of abbreviated breast magnetic resonance imaging for assessing suspicious microcalcification on screening mammography-a prospective study. Eur Radiol 2022;32(2):815–821.
73. Shiraishi M, Igarashi T, Terayama T, Watanabe K, Ashida H, Ojiri H. Breast magnetic resonance imaging for estimation of the tumour extent in patients with pure ductal carcinoma in situ: Comparison between full diagnostic and abbreviated protocols. Eur J Radiol 2020;123:108788.
74. Strobel K, Schrading S, Hansen NL, Barabasch A, Kuhl CK. Assessment of BI-RADS category 4 lesions detected with screening mammography and screening US: utility of MR imaging. Radiology 2015;274(2):343–351.
75. Sickles EA, D'Orsi CJ. ACR BI-RADS follow-up and outcomes monitoring. In: ACR BI-RADS atlas, breast imaging reporting and data system, 5th ed. Reston, Va: American College of Radiology, 2013.
76. Lee JM, Ichikawa L, Valencia E, et al. Performance Benchmarks for Screening Breast MR Imaging in Community Practice. Radiology 2017;285(1):44–52.
77. Garg AS, Rapelyea JA, Rechtman LR, et al. Full-field digital mammographic interpretation with prior analog versus prior digitized analog mammography: time for interpretation. AJR Am J Roentgenol 2011;196(6):1436–1438.
78. Dang PA, Freer PE, Humphrey KL, Halpern EF, Rafferty EA. Addition of tomosynthesis to conventional digital mammography: effect on image interpretation time of screening examinations. Radiology 2014;270(1):49–56.
79. Berg WA, Bandos AI, Mendelson EB, Lehrer D, Jong RA, Pisano ED. Ultrasound as the Primary Screening Test for Breast Cancer: Analysis From ACRIN 6666. J Natl Cancer Inst 2015;108(4):djv367.
80. Borthakur A, Weinstein SP, Schnall MD, Conant EF. Comparison of Study Activity Times for "Full" versus "Fast MRI" for Breast Cancer Screening. J Am Coll Radiol 2019;16(8):1046–1051.
81. Kuhl CK. What the Future Holds for the Screening, Diagnosis, and Treatment of Breast Cancer. Radiology 2023;306(3):e223338.
82. Plevritis SK, Kurian AW, Sigal BM, et al. Cost-effectiveness of screening BRCA1/2 mutation carriers with breast magnetic resonance imaging. JAMA 2006;295(20):2374–2384.
83. Saadatmand S, Tilanus-Linthorst MM, Rutgers EJ, et al. Cost-effectiveness of screening women with familial risk for breast cancer with magnetic resonance imaging. J Natl Cancer Inst 2013;105(17):1314–1321.
84. Geuzinge HA, Obdeijn IM, Rutgers EJT, et al; Familial MRI Screening (FaMRIsc) Study group. Cost-effectiveness of Breast Cancer Screening With Magnetic Resonance Imaging for Women at Familial Risk. JAMA Oncol 2020;6(9):1381–1389.
85. Wanders AJT, Mees W, Bun PAM, et al. Interval Cancer Detection Using a Neural Network and Breast Density in Women with Negative Screening Mammograms. Radiology 2022;303(2):269–275.
86. Yala A, Mikhael PG, Strand F, et al. Multi-Institutional Validation of a Mammography-Based Breast Cancer Risk Model. J Clin Oncol 2022;40(16):1732–1740.
87. Lehman CD, Mercaldo S, Lamb LR, et al. Deep Learning vs Traditional Breast Cancer Risk Models to Support Risk-Based Mammography Screening. J Natl Cancer Inst 2022;114(10):1355–1363.
88. Schrading S, Kuhl CK. Mammographic, US, and MR imaging phenotypes of familial breast cancer. Radiology 2008;246(1):58–70.
89. Arasu VA, Miglioretti DL, Sprague BL, et al. Population-Based Assessment of the Association Between Magnetic Resonance Imaging Background Parenchymal Enhancement and Future Primary Breast Cancer Risk. J Clin Oncol 2019;37(12):954–963.
90. Siu AL; U.S. Preventive Services Task Force. Screening for Breast Cancer: U.S. Preventive Services Task Force Recommendation Statement. Ann Intern Med 2016;164(4):279–296.
91. Causes of death statistics. European Commission. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Causes_of_death_statistics. Updated March 2023. Accessed June 20, 2022.
92. Gladysz K, Borella L. Early Outcomes of Abbreviated Breast MRI for Breast Cancer Screening in Clinical Practice. Royal Australian and New Zealand College of Radiologists. https://epos.myesr.org/poster/ranzcr/ranzcr2021/R-0201. Published 2021. Accessed February 1, 2023.
93. Son D, Phillips J, Mehta TS, Mehta R, Brook A, Dialani VM. Patient preferences regarding use of contrast-enhanced imaging for breast cancer screening. Acad Radiol 2022;29(Suppl 1):S229–S238.