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*Pregled*
*Review*

# COMPARISON BETWEEN BREAST MAGNETIC RESONANCE IMAGING AND CONTRAST - ENHANCED MAMMOGRAPHY

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*Introduction: Imaging modalities such as contrast-enhanced mammography (CEM) and magnetic resonance imaging (MRI) are used as valuable tools for understanding breast pathology. They enable early detection of breast cancer, provide a precise insight into theslesions, and facilitate the monitoring of responses to treatment. Modern CEM improves the detection of breast abnormalitiesfusing contrast agents and the combination of higher energy levels in a single examination. MRI uses magnetic fields and coils to produce detailed images of breast tissue in high-risk cases, and to evaluate suspicious findings with other imaging methods using different sequences.*

*Aim of the paper: The aim of the paper is to introduce CEM and MRI separately, while also identifying the strengths and weaknesses of each technique. This will facilitate their direct comparison.*

*Discussion: CEM excels in detecting multifocal or contralateral lesions, assessing response to treatment, and identifying microcalcifications. Combining the power of mammography and contrast, CEM has the disadvantages of higher radiation dose, artifacts, and possible reactions to the use of iodinated contrast agent. In contrast, MRI provides detailed images, better lesion identification and treatment assessment and possesses exceptional contrast for breast soft tissue evaluation. It has proven invaluable for assessing implant condition and detecting lesions not seen on mammography images. This is crucial for high-risk cases and hiddenstumours. However, MRI has limitations such as artifacts and cost. CEM is a viable alternative to MRI, with high sensitivity.*

*Conclusion: The combined use of CEM and MRI has the potential to transform breast cancer treatment by improving diagnostic accuracy and enabling more personalized treatment approaches, especially in challenging cases, and among high-risk populations with dense breast tissue. With continued technological advances and standardization efforts, CEM and MRI will continue to play a critical role in early cancer detection, lesion characterization, and treatment monitoring, ultimately improving patient outcomes in the field of breast cancer.*

Keywords: MRI, CEM, BREAST CANCER

## INTRODUCTION

Currently, mammography is the leading approach for secondary breast cancer prevention. It outperforms other methods by identifying smaller lesions and enhancing treatment results. Digital breast tomosynthesis (DBT) is gaining ground as an option, particularly for dense breasts. Ultrasound and magnetic resonance imaging (MRI) serve as complementary screenings, advised for those at higher risk (1). Screening, endorsed by the World Health Organization (WHO) and European Society of Breast Imaging (EUSOBI), is crucial to detect potential issues, leading to further evaluations (2, 3).

Contrast enhanced mammography (CEM) combines standard mammography with dual-energy imaging capturing both low-energy (35 keV) and high-energy (45-49 keV) images (4, 5). These images are combined through logarithmic subtraction to highlight iodine accumulation as an indicator ofstumours (5-7). CEM can be performed in 2D, 3D, or a hybrid variation (8). The procedure involves contrast injection before compression followed by image capture after the delay. The exam, typically 7 minutes long, is performed in the second menstrual week and includes multiple projections (6, 9, 10). Techniques like Eklund's projection can exclude implants (8).

MRI scans utilize magnets and radio waves to interact with water molecules in the body creating imagesdanalysed in three planes (8). Stronger magnetic fields improve lesion detection,nresolution, and signal quality (11). Balancing spatial and temporal resolution affects scan time and visualization (12). Breast MRI guided by American College of Radiology (ACR) guidelines produces dynamic contrast-enhanced images. Effective fat suppression enhances cancer detection by leveraging tissue contrast changes (13-16). Higher magnetic field strength and specialized breast coils are recommended for high-resolution images (13, 16).

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Differentiating benign from malignant lesions relies on Dynamic Contrast Enhanced MRI (DCE-MRI) using gadolinium contrast. Conducting DCE-MRI during the second menstrual week reduces false positives (16, 17). Lesion detection uses post-contrast images with subtraction images if fat isn't suppressed. Maximum intensity projections aid rapid detection although artifacts can obscure lesions. Maintaining a pixel size around 1x1 mm optimizes lesion representation (13). Multiparametric MRI including Diffusion Weighted Imaging (DWI) and Apparent Diffusion Coefficient (ADC) mapping, improves accuracy and provides functional data (2). The protocol involves T2, DWI, original T1 and contrast-enhanced series (18). Breast implant pathology diagnosis employs three sequences (8).

CEM results align with Breast Imaging-Reporting and Data System (BI-RADS) 0-6dcategories, and combining CEM with other methods completes the assessment (18). However, BI-RADS lacks malignancy prediction (13). Enhancing breastrtumour diagnosis involves adding malignancy potential, BI-RADS assessment and CEM intensity to mammography and CEM. Incorporating breast density and background parenchymaltenhancement (BPE) further improves accuracy (4). The Kaiser scale aids MRI interpretation by categorizing masses and estimating malignancy likelihood (18). BI-RADS includes breast MRI details while the improvement curve and curvestypes of aid interpretation with different types indicating malignancy levels (12, 17).

## AIM OF THE PAPER

The aim of the paper is to introduce CEM and breast MRI separately, highlighting their strengths and weaknesses, which facilitates their comparison for assessment of breast anatomy andypathology.

## DISCUSSION

### ADVANTAGES OF CEM

The straightforward and concise nature of the CEM procedure makes it a preferred X-ray screening method for breast cancer diagnosis (8).

### INDICATIONS FOR CEM

CEM is used for preoperativertumour staging including multifocal/contralateral detection,rtumour size assessment and monitoring Neoadjuvant Chemotherapy (NAC) response (19). CEM complements or substitutes mammography for abnormal findings clarifying unclear mammograms, diagnosing breast cancer and screening high-risk or dense-breasted women (10, 20).

#### Preoperative assessment of treatment

Thorough preoperative imaging for suspected multiple breast cancers starts with mammography and ultrasound followed by DCE-MRI (21). CEM in preoperative tumor staging accurately estimates size has a high positive predictive value for detecting extra lesions and marginally reduces identification of additional foci (6).

#### Diagnostics of microcalcifications

Low-energy CEM detects lesions from calcification clusters causing distortion (15). DBT differentiates ultrasound-detected problems well, while CEM distinguishes malignancy from benign distortion through strong staining. A biopsy is needed for distorted ultrasoun/ or DBT; CEM's value is limited in weaker-enhanced lower-grade malignancies (10). CEM's advantage for calcification assessment is uncertain. Suspicious mammography calcifications warrant biopsy regardless of CEM enhancement (6).

#### Diagnostics of Multifocal Multicentric Breast Carcinoma (MMBC)

CEM combines morphological mammography withrtumour vascularity assessment which helps in malignancy detection (21). It excels in symptomatic cases, with whole-contrast exams preferred (10). CEM's popularity grows due to merging Full Field Digital Mammography (FFDM) benefits and MRI's lesion enhancement (22). It identifies enhancing lesions and various features on low-energy images, including microcalcifications, foci, distortions, and spiculated lesions, detecting additional low-gradestumours (23). CEM offers a comprehensive approach for MMBC diagnosis using low-energy and recombined imaging (21).

#### Screening in a high-risk population

Screening aims to catch suspicious findings leading to further tests. CEM spots small hidden cancers in dense and heterogeneous breasts. It complements techniques for dense breasts avoiding misses (2). CEM improves detection in high-risk patients with less radiation than DBT (24). It revealsstumours in dense and heterogeneous breasts by exploiting angiogenesis ensuring accurate diagnoses (2).

#### Monitoring response to NAC

NAC reducesrtumour size and aids breast-conserving surgery success. Pathologic response to NAC correlates with better prognosis. However, 10-35% show chemotherapy resistance potentially delaying surgery. Timely pathologic response assessment is crucial, guiding surgery and treatment choices (25). CEM assesses treatment response and so baseline CEM before treatment is vital for comparison (10). Initial CEM use for NAC response is promising, and low-energy imaging eliminates extra FFDM streamlining the process (6).

#### Implementation and profitability of CEM modality

CEM integrates well into daily workflows after inconclusive mammography and ultrasound results (23). Radiologists familiar with mammography can interpret CEM images easily (15). Diagnostic performance is similar for

radiologists with or without prior CEM experience, indicating a manageable learning curve, especially for those skilled in FFDM and breast MRI (6). CEM's benefits include fast treatment progress and freeing up MRI resources for other uses like additional screening. It's poised to replace DCE-MRI for breast cancer staging, saving costs for healthcare organizations with unit CEM costs likely to decrease as testing numbers grow (26).

### The ratio of false positive and false negative findings

CEM offers high sensitivity, low false-positivesrates, and potential as an MRI alternative for breast cancer staging and diagnostics. Its significant negative predictive value indicates unlikely malignancy when CEM shows no improvement (27). CEM confirms benign findings by showing no enhancement in postoperative areas. False positives relate to fat necrosis; false negatives result from extensive fibrosis limiting visualisation (4). CEM accurately estimatesrtumour size with comparable or slightly lower additional site detection rates and a superior positive predictive value for extra lesions (6).

## ADVANCEMENT OF CEM MODALITY

Artificial intelligence and radiomics are integrated into CEM searches differentiating invasive from non-invasivestumours (6). A new biopsy technique applies CEM with dual energies for stereotactic or wire localization (10). For now, only one commercial device offers CEM-guided biopsy (28). CESM-Bx provides flexible and quicker results (2 days) with a 30-minute procedure compared to DCE-MRI-guided biopsy (about 60 minutes) (29).

## DISADVANTAGES OF CEM

Introducing CEM to a busy breast imaging practice raises workflow concerns. Additional steps like setting up contrast injection, patient contraindication assessment, creatinine testing and IV-line insertion impact examination duration (4).

### Radiation dose

CEM results in higher radiation exposure compared to FFDM and DBT (5). The dose, varying from 20% to 80%, depends on settings, breast thickness and device. Though lower than FFDM + DBT, CEM adheres to guidelines not significantly increasing lifetime exposure risk (6). Dose reduction methods include anti-scatter net removal and software correction (5). Manual CEM mode and efforts to minimise exposure are employed (30).

In comparisons, CEM's dose increased by 106-108% but was lower than DBT in one case (10). Bilateral CEM averages 4.90 mGy, about 30% higher than low-energy mammography, and is still suitable for clinical adoption (31). Ongoing efforts minimise CEM radiation exposure with Average Glandular Dose (AGD) surpassing digital mammography and DBT (5). Denser breasts may require higher doses for image quality (31).

### Artifacts

European Reference Organisation for Quality Assured Breast Screening and Diagnostic Services (EUREF) criteria assess image quality for performance and diagnostics addressing lesion visibility and tissue clarity (32). CEM imaging with breast implants might yield suboptimal outcomes but proper technique and offset views can mitigate this (20). Artifacts might limit small lesion detection in prospective CEM screening prompting manufacturers to develop artifact reduction algorithms to improve image quality (20). The CEM algorithm employs post-processing to enhance raw low-energy images and dual-energy subtraction images highlighting contrast uptake (20). Common artefacts include "breast-in-breast" with chest-in-chest more in cranio-caudal and ripple and skinfold enhancement more in mediolateral views (20). The NEW algorithm effectively reduced various artifacts preserving contrast uptake but not all skinfold enhancement artifacts were reduced (Figure 1.) (20).

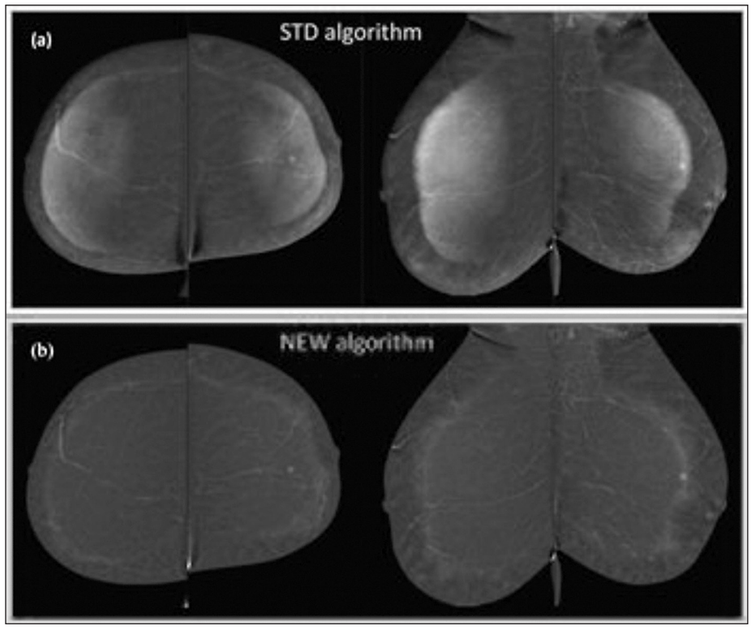


Figure 1.
*NEW algorithm*

Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9098782/bin/13244_2022_1211_Fig2_HTML.jpg





Artifact presence can influence BPE classification which is considered a potential risk factor (20). CEM artifacts can be divided into two main categories: specific and non-specific. Specific artifacts are exclusive to CEM and are not visible through other imaging methods. In CEM unique arefacts are referred to as CEM-related factors and they collectively contribute to the distinctiveness of CEM imaging (33). Markers after breast biopsy may appear differently on CEM images. Ruptured implants can causesartefacts that obscure abnormalities. Postbiopsy cysts, calcifications or hematomas might show rim-enhancing hypodensity on CEM images. Halo artefact exaggerats boundaries due to radiation scatter differences. Ripple artifacts appear in mediolateral views from patient movement or heart pulsation. Misregistration artifacts arise from misaligned low and high energy images often involving clips,svessels, and calcifications. Enhanced skin lesions with a "horizon linetartefact" may result from radiation scatter and skin thickness variations (33). The ghosting artifact is caused when a previous image overlaps with the next due to fast transitions in CEM acquisitions. Though rare, recalibrating the machine to erase the memory of the previous image can solve this issue (33). Motion artefacts can degrade image quality and affect diagnosis. Implementing motion correction techniques is the best solution. Although lymph node visibility might slightly decrease on recombined images due to motion correction it's acceptable as visibility on FFDM and low-energy images remains unchanged. Motion correction reduces diagnostic uncertainties and false negatives potentially saving costs and reducing extra procedures like MRI or ultrasound-guided biopsy (34). On the other hand, non-specific artefacts can also be detected using other techniques like mammography (33). Motion artefacts in CEM are fewer than in previous techniques, but more common than in traditional mammography due to longer exposure and compression. Hair artefacts should bedavoided, and antiperspirant can mimic microcalcifications. Air trapping artifacts result from incomplete skin-detector contact masking abnormalities (33). Contrast splashing during administration might cause white dot artifacts resembling microcalcifications on recombined images. Temporary contrast retention in blood vessels, often due to premature breast compression is common but doesn't impact image quality and doesn't appear on subsequent images of the same breast (33).

### Contraindications

While risks of ionizing radiation exposure are usually outweighed by benefits in specific cases, dose estimation gains importance when imaging healthy individuals as in population screening using techniques like CEM (31).

Screening patients for contrast allergies is crucial. Precautions involve elderly or renal risk patients and avoiding iodinated contrast in abnormal renal function cases (6). CEM needs resuscitation-capable facilities and caution with kidney issues, allergies or advanced age (2). Note that CEM is contraindicated in patients with renal failure and those at risk need renal function assessment as in contrast-enhanced CT. Premedication for allergic reactions isn't advised; alternatives like DCE-MRI may be considered (10).

In conventional breast imaging, foetal mammographic doses are below harmful levels. Mammographic sensitivity remains high during pregnancy showing its effectiveness. While research on screening mammography in breastfeeding is limited, it benefits high-risk individuals. Though not contraindicated during lactation, some delay due to interpretation concerns. To enhance mammographic sensitivity in lactating women, breastfeeding before the exam is advised for better image quality. Decisions on breastfeeding and screening mammography involve patient-provider discussions considering individual circumstances (35).

### False positive and false negative findings

Overlooking breast cancer near the chest wall's inner quadrant is a concern. CEM before puncture is vital with muscle relaxants recommended for thorough imaging (21). CEM, like any other imaging has false positives and negatives. High BPE lesions might be missed while benign ones show unnecessary enhancement (10). CEM struggles to visualize microcalcifications from low-grade ductal carcinoma in situ (DCIS) on subtracted images (2).

## ADVANTAGES OF BREAST MRI

DCE-MRI is the most sensitive imaging method for breast cancer detection and staging (15). Breast MRI is vital for various purposes like assessing known cancer extent and monitoring treatment (36). Tailoring thresholds based on risk is crucial (10).

## INDICATIONS

Breast MRI is advised for various purposes, like assessing known cancer extent, investigating recurrence, screening high-risk patients, resolving inconclusive results, finding hiddenstumours and monitoring NAC and treatment (36).

### Preoperative assessment of treatment

Preoperative MRI can reveal hidden lesions missed byymammography, but surgical impact must be confirmed pathologically. Multiparametric protocols help classify lesions as benign reducing unnecessary biopsies. MRI-guided ultrasound biopsies 57.5% of indeterminate lesions,gfavouring masses. For suspicious lesions missed by MRI-guided ultrasound, MRI-guided biopsies are used instead (13). Pre-treatment MRI resolves size disparities between modalities and guides eligibility for partial breast radiation therapy. Dense breasts, invasive lobularacarcinoma, or age below 50 warrant preoperative MRI, which is well-established in clinical practice (12). While DCE-MRI spots additional lesions for varied therapies it doesn't consistently improve survival outcomes (2).

### Monitoring response to NAC

Breast MRI distinguishes NAC responders and detects residual disease post-treatment (12). 3D software allows

semi-automated volumetric measurements. Response is indicated by curve analysis orgmodelling, early gain reduction which predicts final response and increased ADC values that shows positive response. MRI excels in assessing fibrosis after treatment or biopsy changes challenging other methods. While correlating with post-NACrtumour size, MRI can underestimate or overestimate due to microscopic areas. Hormone receptor-positive/HER2-negativestumours pose challenges, needing tailored interpretation considering subtype and MRI phenotype. Delayed phase images aid surgical sizing post-NAC particularly for residual ductal carcinoma in situ (13).

### Screening in a high-risk population

Breast MRI's advantage lies in its independence from breast density, unlike mammography which can be hindered by this factor (37). MRI screening research predominantly focuses on high-risk women due to lower mammography sensitivity (13). It's valuable for cancer detection, characterizingstumours, assessing disease extent, treatment response, guiding biopsies and localizations. Breast MRI sensitivity ranges from 77% to 100%, surpassing other methods in high-risk screening (15). DCE-MRI is recommended for high-risk individuals with up to 97% sensitivity due to its neovascularity detection ability. Many women with intermediate risk, dense breasts, family history, high-risk lesions or survivors can also benefit (6). Microsimulation models show adding biannual MRI to mammography, as shown in the DENSE trial, could save 8.6 lives per 1000 women with EUR 150,000 per life saved or EUR 22,500 per quality-adjusted life-year cost-effectiveness. MRI-only strategies without mammography are dominant. MRI every 4 years saves 7.6 lives at €75,000 per life saved or €11,500 per quality-adjusted life-year. Using MRI alone every 2-3 years may be practical to detect faster-growing cancers with a slight rise in false positives (3). For those with Paget's disease, MRI is recommended when standard methods miss cancer (12).

### Diagnosis of silicone rupture in the breast

DCE-MRI is currently the preferred method for evaluating breasts with silicone implants (Figure 2.). However, gadolinium's enhancing effect can complicate diagnoses by causing overlapping patterns in various lesions. DCE-MRI-guided biopsies are crucial for accurate determination (29). The silicone leakage detection protocol differs from breast cancer assessment utilizing no-gadolinium contrast and specific sequences that differentiate silicone and water despite magnetic field issues, eliminating the need for DWI and DCE-MRI (12).

For diagnosed breast cancer patients, MRI helps assess disease extent and find additional lesions, including contralateral ones (2). It's beneficial for evaluating surgical margins and identifying hidden cancer though distinguishing postoperative changes can be tough with a low negative predictive value of around 45% (12). MRI detects hidden contralateral cancer in 5.5% to 9.3% of unilateral cases, often small and sometimes DCIS. This serves as high-risk screening surpassing BRCA mutation yields (13). DCE-MRI aids metaplastic breast cancer diagnosis but has variable specificity (37% to 97%), missing calcifications and potentially leading to unnecessary biopsies (21).

### Diagnostics of invasive lobular carcinoma

Breast MRI is effective in detecting about 75% of cancers within 1 cm of their true size, with comparable rates of both overestimation and underestimation. However, its accuracy decreases

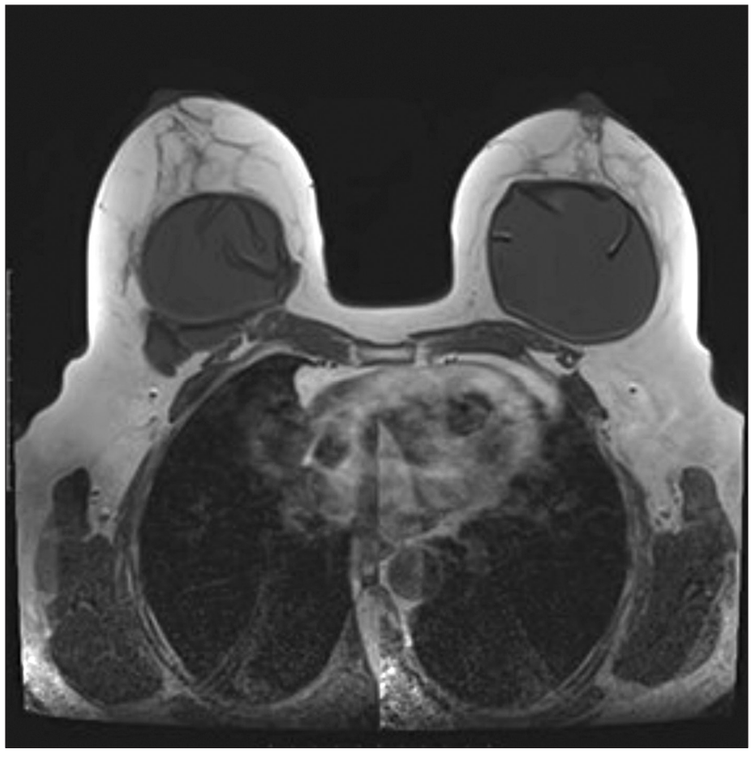

Figure 2.
*MRI of silicone rupture*

Source: https://prodimagesstatic.radiopaedia.org/images/4640946/94b65f0672549b7e67894399b1d719_big_gallery.jpg





for largerstumours and non-mass enhancements. The benefits of MRI size assessment are particularly notable for invasive lobular carcinomas, where conventional methods and clinical exams have limitations (38). DCE-MRI not only evaluates size changes but also captures morphological alterations, which is a key advantage (25). MRI plays a significant role in accurately staging invasive lobular carcinoma, addressing underestimations seen in mammography and ultrasound. Its utilization has led to reduced re-excision rates for this subtype ranging from 11% to 18% (2).

### Sensitivity and specificity of modality

Breast cancer's high sensitivity to MRI results from its reliance on new blood vessel growth for nutrients.sTumours can't exceed 2 mm without these vessels (39). MRI sensitivity varies (75.2% to 100%), exceeding 80%, while specificity ranges (83% to 98.4%) increasing with prevalence and incidence rounds, showing lower initial screening specificity. Positive predictive values for biopsy range (11% to 40%), similar to mammography with 40% of false positives linked to enhanced high-risk lesions, impacting screening choices (39).

### Advancement of MRI modality

Gadolinium-free MRI methods are gaining traction for situations with gadolinium challenges like pregnancy,sallergies, and breastfeeding. They're employed in breast diffusion MRI for high-risk screening and problem-solving scenarios (12). Established techniques like DWI and proton Magnetic Resonance Spectroscopy (MRS) offer added parameters in breast imaging. Newer methods like CEST, BOLD, sodium imaging and hyperpolarized MRI are being explored. Ultra-high-field MRI at 7 Tesla improves signal-to-noise ratio (SNR) but brings challenges like longer T1 relaxation times and reduced image quality (17).

### DWI

DWI uses motion-sensitive gradients in T2-weighted images to capture water diffusionrbehaviour (13). Its advantage lies in calculating ADC for diffusion quantification. Challenges include variable results in distinguishing benign from malignant lesions and inconsistent image quality due to MRI differences. Combining DWI with other sequences is advised for comprehensive evaluation (40). In uncertain cases, multiparametric MRI with DWI can serve as a secondary assessment (40). DWI is valuable for non-invasivertumour assessment providing insights intortumour characteristics (17). It's also a helpful alternative when contrast agents are contraindicated (40).

### Abbreviated MRI

To counter high MRI costs affecting total examination expenses, attention has turned to shortened breast MRI protocols called abbreviated breast MRI. The goal is improved efficiency and reduced viewing expenses while providing a more accessible and cost-effective approach (3). Abbreviated breast MRI uses specific sequences before and after contrast meeting ACR standards for breast MRI accreditation. Despite briefer scanning and table times, abbreviated protocol's sensitivity in detecting breast cancer equals full DCE-MRI, proving its effectiveness (41).

### Ultrafast MRI

DCE-MRI uses ultrafast sequences lasting about 5 seconds, capturing rapid images during contrast passage. Techniques like TWIST, 4D-TRAK, TRICKS, etc., involve under sampling and view-sharing. Ultrafast breast MRI, for diagnosis and screening, replaces initial DCE-MRI phases with quick sequential post-contrast images. Scan time is under 10 minutes including a T2-weighted sequence (12).

### Synthetic MRI

Synthetic MRI is an innovative method creating various contrasts from a single scan through quantitative values of different physical properties. Parameters are adjustable mathematically, reducing rescans, saving time and enhancing screening efficiency. It holds potential for synthesizing contrast-enhanced images from unenhanced ones. This is beneficial for contrast-sensitive patients like those with allergies, asthma or pregnancy and for those with discomfort in long MRI sessions (42).

### Artifacts

Despite efforts to optimize MRI protocols with fat suppression techniques and adjustments to SNR, resolution and imaging planes, subtraction artifacts remain a challenge. These artifacts affect diagnostic image quality, especially in subtraction images, without being linked to known chemical shift artifacts (14).

Patient-related artifacts in breast MRI result from poor positioning, inadequate coil-tissue spacing, and breast compression. Motion during imaging leads to blurring and reduced quality. Magnetic susceptibility artifacts can arise from metal in the body, affecting MRI results (43).

Proper coil selection, fat suppression and correction of phase-encoding artifacts are essential to avoid artifacts caused by technical factors. Pseudolesions can be differentiated from real lesions. Envelope and zebra/moiré artifacts can be minimized by modifying field of view (FOV) and phase encoding. Chemical shift artifacts stem from water-fat resonance differences and can be reduced with techniques like FAT SAT. RF interference artifacts result from external radiofrequent sources and can be managed by removal or gradient adjustments (43).

### Contraindications

Breast MRI is an advanced but limited procedure. The search is on for a more affordable, accessible and patient-friendly alternative diagnostic test (36).

DCE-MRI's uncertain clinical significance raises doubts about its routine use for high-risk screening (4). Injecting contrast agents is inconvenient,eexpensive, and uncomfortable, despite the safety of

current agents (39). Nephrogenic systemic fibrosis cases emerged in 2006 due to gadolinium-containing contrast use in individuals with kidney problems (44).

Patients experiencing claustrophobia or anxiety before a breast MRI can receive mild sedatives. If severe claustrophobia persists and the MRI is essential, procedure can be done under general anaesthesia (8).

Most metal implants are safe in MRI but some like cochlear implants and certain cardiac devices are prohibited. Technicians must check for implants to avoid risks. X-rays may help detect metal. Objects near eyes and iron tattoos rarely affect MRI. Dental fillings and prostheses generally don't disrupt but could cause image issues especially in the face or brain (8).

MRI carries potential risks during pregnancy due to teratogenic effects. Low-field MRI machines may have minimal risks. Recent studies show no major harm to infants exposed to MRI. Gadolinium'slfoetal toxicity is uncertain; European radiology groups are cautious, while the ACS advises against DCE-MRI in pregnant women (34). Reproductive-age patients should be asked about pregnancy before exams. Pregnant women in the first trimester should avoid strong magnetic fields except when benefits outweigh risks. Gadolinium is recommended only if vital for treatment (8).

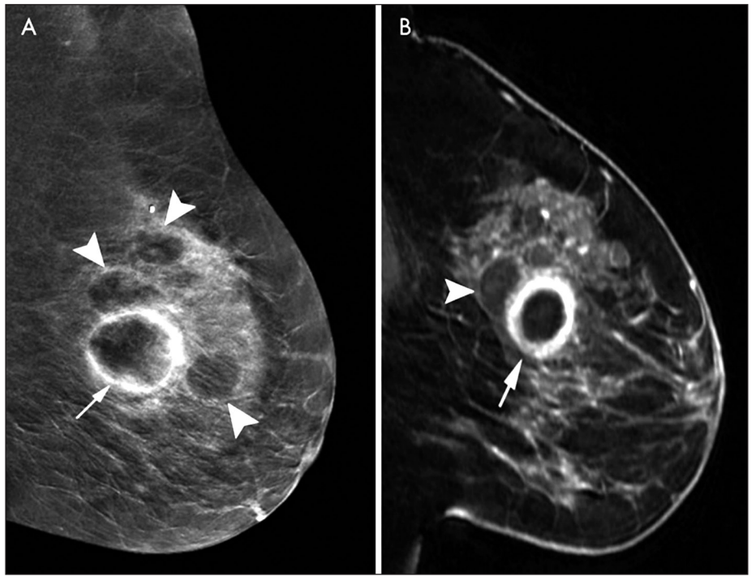


Figure 3.
*Presentation of the same lesion by CEM and MRI method*

Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7997616/bin/radiol.2021201948.fig4.jpg

### False positive and false negative findings

Auditing outcomes and evaluating false positives in DCE-MRI is crucial due to the overlap between benign and malignant enhancing lesions ensuring appropriate diagnostic tests are done (12). Invasive carcinomas often show enhancement with contrast while some DCIS does not (45). Extended screening, like breast MRI, increases the chance of false alarms requiring additional evaluations. Some cancers found through screening might not have caused symptoms, leading to "overdiagnosis" (3). MRI-guided biopsies are precise but time-consuming and costly (28). Unlike other methods, MRI lacks real-time tracking of biopsy needles (46). DCE-MRI can yield false negatives, especially for invasive lobular carcinoma and DCIS, lacking post-contrast enhancement. Double-reading, cognitive processgunderstanding, and bias awareness are needed to improve accuracy and reduce false negatives (12).

### Harmfulness of Specific Absorption Rate (SAR)

High-field MRI's safety concern is about temperature changes caused by SAR in the body. High energy deposition, especially in sequences with frequent radiofrequency pulses like fast spin-echo, can pose risks (11).

### Demanding of modality

DCE-MRI protocols lack standardization, including traditional and shortened ones. Ultrafast breast MRI has even lower standardization (12). Slow adoption of breast MRI for screening is due to limited scanner availability and high costs. European guidelines often exclude lower-risk women due to cost-effectiveness concerns. Detection frequency and MRI cost influence cost-effectiveness. Some undiagnosed cases result from interpretation or treatment errors, often due to lack of experience (39). Breast MRI analysis requires breast imaging specialists who understand mammography and ultrasound. Experience improves performance over time (13). While breast MRI is sensitive, specificity varies, affecting its impact on surgical outcomes. MRI may lead to mastectomy due to additional findings and limited biopsy options. Surgeon experience and discussions affect re-excision rates. MRI is reserved for specific cases due to limitations (19).

## COMPARISON OF BREAST MRI AND CONTRAST MAMMOGRAPHY

Although CEM lacks delayed images like DCE-MRI, it can use lesion enhancement to create similar images (Figure 3.) (10). Differences in lesion dimensions exist between CEM, breast MRI, and histopathology due to breast compression during procedures. A slight overestimation of lesion sizes on images does not impact treatment as surgical excisions includs safety margins (15).





CEM detects enhancing lesions categorized as focal,emassive, or non-massive enhancements. Both malignant and benign lesions caneenhance, and malignancy might appear as asymmetric enhancement without an abnormality on low-energy images. Suspicious non-enhancing lesions on low-energy images should not be dismissed as benign. Like DCE-MRI some cancers might show minimal enhancement on CEM. Enhanced lesions may reveal abnormal areas on recombined images (10). Recent meta-analysis supports CEM as an alternative to DCE-MRI withefavourable pooled sensitivity (Figure 4.) and specificity (Figure 5.) and therefore CEM is proposed for initial breast lesion assessment (9). MRI tends to overestimatertumour diameter slightly while CEM doesn't (47). CEM's accuracy inrtumour size estimation matches or surpasses MRI and especially benefiting dense breasts (4).

CEM is suitable for MRI-ineligible patients due to allergies, pacemakersiac-laustrophobia, or physical reasons. CEM excels in evaluating suspicious mammography findings, dense breast screening and post-chest radiation screening. It's particularly helpful for detecting calcification-based DCIS often missed on MRI (48). MRI identifies both invasive cancers and DCIS while mammography mainly detects DCIS (13). CEM outperforms MRI in spotting non-invasive cancers, especially those with calcifications (21). CEM accurately measureortumour size and using breast MRI solely for size assessment isn't needed, except for suspected multifocal cancer cases. Breast MRI remains preferred for multifocal cases due to limited evidence on CEM's accuracy (47). CEM's secondary cancer detection matches DCE-MRI (10). Patients prefer CEM over MRI for both diagnostic and screening purposes due to factors like shorter procedure time, greatertcomfort, and reduced noise. CEM's image acquisition is quicker (7-10 minutes) compared to MRI (30-60 minutes), enhancing patient tolerance and radiologist efficiency.

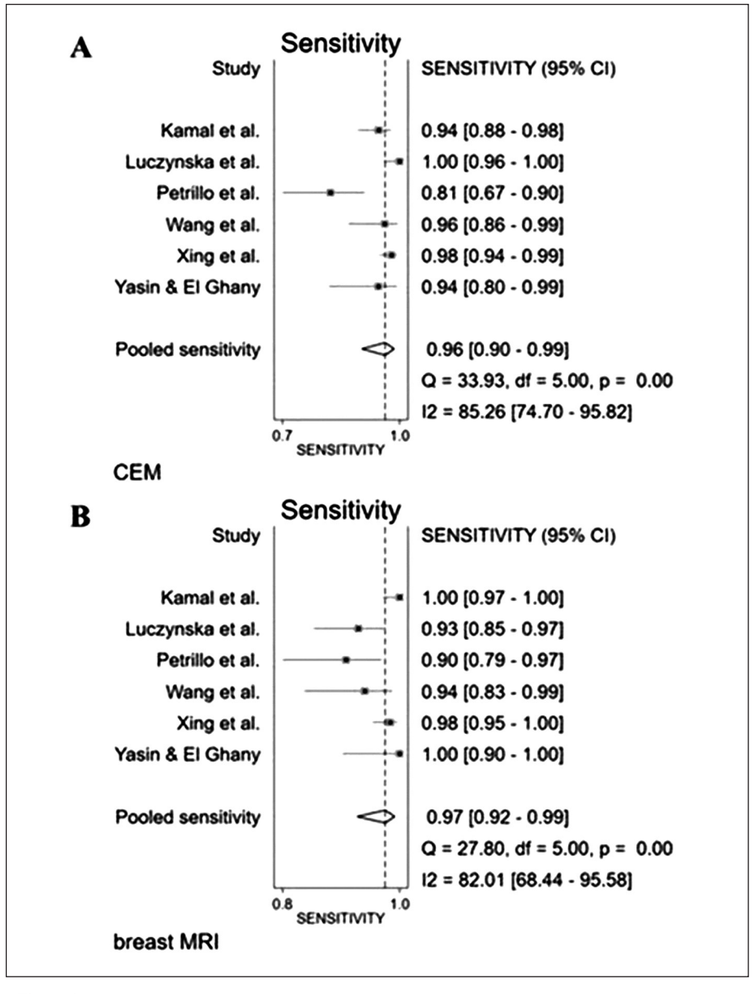


Figure 4.
*Presentation of the meta-analysis of the sensitivity of CEM and MRI*

Source: https://www.jcancer.org/ms/getimage.php?name=jcav14p0174g002.jpg&type=thumb

Despite abbreviated MRI protocols, CEM remains more effective during initial mammograms. It's also cost-effective with around four times lower cost than full MRI. MRI's cost, space requirements and safety considerations limit its availability, while CEM can be easily integrated into existing mammography sites, improving access. CEM excels ag visualising certain cancers that MRI might miss due to differences in contrast agents and mechanisms (4). CESM demonstrates significantly enhanced positive predictive value and specificity compared to MRI, resulting in fewer false positive interpretations. Therefore, when malignancy is suspected based on clinic imaging, performing a CEM exam offers sensitivity and specificity almost on par with breast MRI staging (2, 4). Lesion details are unveiled using current digital detectors with spatial resolution up to 10 times greater than breast MRI (15). However, using CEM specifically to evaluate suspected calcifications provides no clear benefit. Thustolike MRI, suspicious calcifications on mammography should be biopsied regardless of CEM enhancement (6). CEM's limitation compared to DCE-MRI is a smaller field of view potentially affecting detection of chest wall invasion, internal metastases

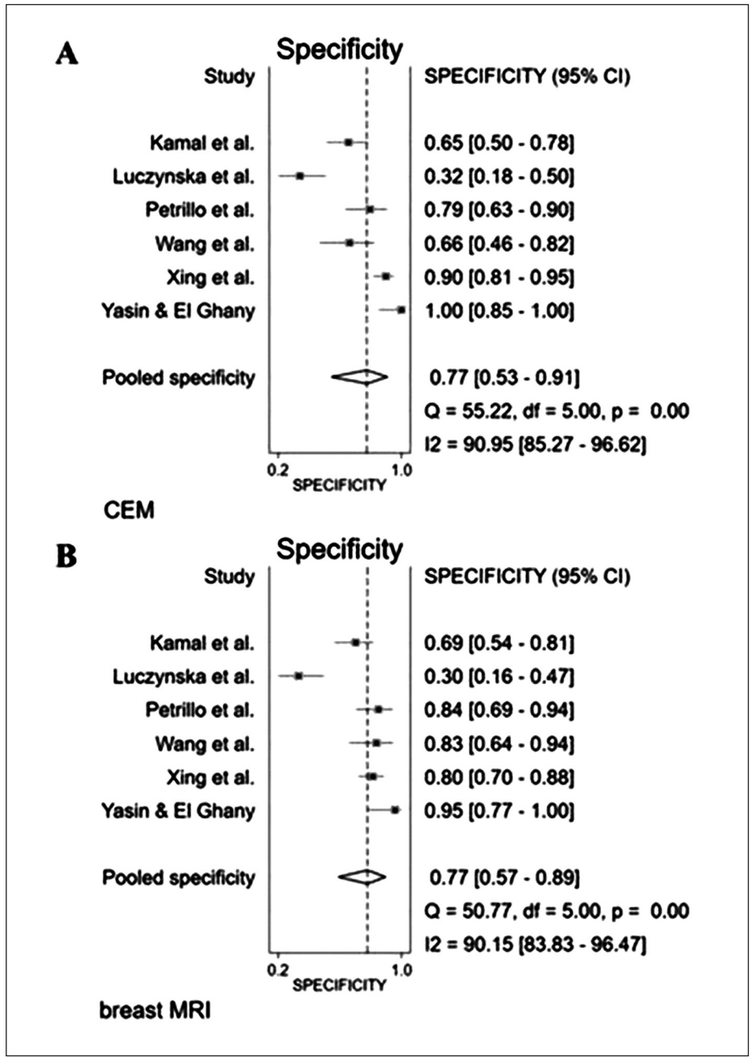


Figure 5.
*Presentation of the meta-analysis of the specificity of CEM and MRI*
Source: https://www.jcancer.org/ms/getimage.php?name=jcav14p0174g003.jpg&type=thumb

and axillary nodes. DCE-MRI's broader coverage yields superior visualization. Note that moderate-to-severe BPE could risk lacking enhancing lesions. Unlike DCE-MRI, BPE on CEM seems minimally influenced by menstrual cycle timing (10).

Concern arises from the significant variation in the three available meta-analyses' findings, attributed to differing criteria for study selection, which is leading to limited overlap. Reliable, evidence-based results require consistent criteria and methodologies in meta-analyses (19).

## CONCLUSION

Breast cancer imaging has advanced, using methods like CEM and MRI for early detection, precisisdiagnosis, and treatment planning. Combining CEM and MRI improves accuracy, especially in complex cases. While valuable, these techniques have drawbacks like radiation and cost. The evolution from film-based mammography to digital systems, enhanced by CEM and the detailed soft tissue view from MRe has transformed breast cancer imaging. Standardized reporting systems like BI-RADS aid communication. Despite challenges, ongoing progress continues to enhance outcomes.

All the data are part of the results of the undergraduate thesis "Comparison between breast magnetic resonance imaging and contrast-enhanced mammography", written at the University Department of Health Studies, University of Split (49).

*Abbreviations:*

ACR - American College of Radiology
ADC - Apparent Diffusion Coefficient
AGD - Average Glandular Dose
BI-RADS - Breast Imaging-Reporting and Data System
BPE - Background Parenchymal Enhancement
CEM - Contrast enhanced mammography
DBT - Digital Breast Tomosynthesis
DCE-MRI - Dynamic Contrast Enhanced MRI
DCIS - Ductal Carcinoma in situ
DWI - Diffusion Weighted Imaging
EUREF - European Reference Organisation for Quality Assured Breast Screening and Diagnostic Services
EUSOBI - European Society of Breast Imaging
FFDM - Full Field Digital Mammography
FOV - Field of View
MMBC - Multifocal Multicentric Breast Carcinoma
MRI - Magnetic Resonance Imaging
MRS - Magnetic Resonance Spectroscopy
NAC - Neoadjuvant Chemotherapy
SAR - Specific Absorption Rate
SNR - Signal-to-Noise Ratio
WHO - World Health Organization

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*Sažetak*

USPOREDBA IZMEĐU MAGNETNE REZONANCIJE DOJKI I KONTRASTNE MAMOGRAFIJE

*Jelena Teklić, Tatjana Matijaš*

*Uvod: Modaliteti snimanja poput kontrastne mamografije (CEM) i magnetske rezonancije (MRI) koriste se kao vrijedni alati za razumijevanje patologije dojke. Omogućuju rano prepoznavanje karcinoma dojke, daju precizne uvide u lezije i olakšavaju praćenje odgovora na liječenje. Moderni CEM poboljšava otkrivanje abnormalnosti dojke korištenjem kontrastnih sredstava i kombinacijom više razina energije u jednom pregledu. MRI koristi magnetska polja i zavojnice za detaljne slike tkiva dojke u visokorizičnim slučajevima i za procjenu sumnjivih nalaza kod drugih metoda snimanja s različitim sekvencama.*

*Cilj rada: Cilj rada je zasebno predstaviti CEM i MRI, uz identificiranje prednosti i slabosti svake tehnike što će olakšati njihovu izravnu usporedbu.*

*Rasprava: CEM se ističe u otkrivanju multifokalnih ili kontralateralnih lezija, procjeni odgovora na liječenje i identificiranju mikrokalcifikacija. Kombinirajući snagu mamografije i kontrasta, CEM ima nedostatke veće doze zračenja, artefakata i mogućih reakcija na korištenje jodnog kontrastnog sredstva. Nasuprot tome, MRI pruža detaljne slike, bolju identifikaciju lezija i procjenu liječenja te posjeduje izniman kontrast za procjenu mekog tkiva dojke. Pokazao se neprocjenjivim za procjenu stanja implantata i otkrivanje lezija koje se ne vide na mamografskim snimkama. To je ključno za visokorizične slučajeve i skrivene tumore. Međutim, MRI ima ograničenja poput artefakata i troškova. CEM je održiva alternativa MRI, s visokom osjetljivošću.*

*Zaključak: Kombinirana uporaba CEM-a i MRI-a ima potencijal promijeniti liječenje karcinoma dojke poboljšanjem dijagnostičke točnosti i omogućavanjem personaliziranijih pristupa liječenju, posebno u zahtjevnim slučajevima i među populacijama visokog rizika s gustim tkivom dojke. Sa stalnim tehnološkim napretkom i naporima za standardizaciju, CEM i MRI i dalje će igrati ključnu ulogu u ranom otkrivanju karcinoma, karakterizaciji lezija i praćenju liječenja, u konačnici poboljšavajući ishode liječenja pacijenata u području karcinoma dojke.*

Ključne riječi: MRI, CEM, KARCINOM DOJKE

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