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Optimizing Surgical Decision-Making in Breast Cancer: The Role of Preoperative Magnetic Resonance Imaging

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ABSTRACT

Background: Breast cancer remains the most common malignancy among women worldwide, and its optimal surgical management continues to evolve with advances in imaging technologies. Preoperative magnetic resonance imaging (MRI) has emerged as a powerful diagnostic tool, capable of providing superior soft-tissue contrast, high sensitivity for tumor detection, and detailed assessment of disease extent compared to conventional imaging modalities such as mammography and ultrasound. These characteristics have raised the question of whether preoperative MRI can meaningfully improve surgical decision-making, reduce re-excision rates, and ultimately improve oncologic outcomes.

The primary aim of this review is to critically evaluate the role of preoperative MRI in guiding surgical management of breast carcinoma, with a focus on breast-conserving surgery (BCS), mastectomy, margin status, and contralateral breast cancer detection. We will also explore subgroups where MRI may confer unique benefits, including women with invasive lobular carcinoma, young patients, and those with dense breast tissue. Furthermore, the discussion will address the potential downsides of MRI, including increased mastectomy rates, false-positive findings, overtreatment risks, and health system cost implications.

While MRI demonstrates unparalleled sensitivity in detecting both unifocal and multifocal disease, controversy persists regarding whether these advantages translate into better surgical or long-term outcomes. Some evidence suggests that MRI reduces the need for re-excisions and enhances surgical precision, while other studies point to increased mastectomy rates without clear survival benefits. Importantly, preoperative MRI may help personalize surgical planning when integrated with patient preferences, tumor biology, and multidisciplinary decision-making.

Ultimately, the role of MRI in breast cancer surgery should not be assessed solely on its diagnostic capabilities, but rather in terms of its impact on patient-centered outcomes, quality of life, and healthcare resources. This review aims to synthesize current evidence and provide clarity on when, how, and for whom preoperative MRI is most beneficial in surgical oncology practice.

Keywords: Surgical Decision, Breast Cancer, Preoperative Magnetic Resonance Imaging

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INTRODUCTION

Breast carcinoma remains a major public health challenge, accounting for approximately one in four cancer diagnoses among women globally [1]. Surgical management continues to be the cornerstone of curative treatment, and the evolution of breast cancer surgery has shifted toward breast conservation and minimizing morbidity while maintaining oncologic safety [2]. Preoperative imaging plays a pivotal role in determining surgical strategy, with mammography and ultrasound being the traditional mainstays. However, their limitations in accurately assessing tumor extent, multifocality, and contralateral disease have prompted increasing interest in preoperative magnetic resonance imaging (MRI) [3].

MRI offers superior sensitivity compared with conventional imaging, detecting up to 16% more cancers that would otherwise go unrecognized [4]. This has significant implications for surgical planning, especially when considering breast-conserving surgery versus mastectomy. Despite these advantages, preoperative MRI remains controversial due to concerns of overtreatment, higher mastectomy rates, and uncertain impact on survival outcomes [5]. The lack of consensus has generated considerable debate in surgical oncology, underscoring the need for comprehensive evaluation of its benefits and limitations.

The aim of this review is to analyze the impact of preoperative MRI on surgical management of breast carcinoma, focusing on its influence on surgical decision-making, re-excision rates, mastectomy trends, and subgroup benefits. Furthermore, this review identifies existing research gaps, particularly in long-term outcomes and cost-effectiveness, and highlights areas where further investigation is necessary to optimize patient care. By consolidating current evidence, this review seeks to provide surgical oncologists with a nuanced perspective on the role of preoperative MRI in breast cancer treatment.

Overview Of Preoperative MRI In Breast Carcinoma

Magnetic resonance imaging (MRI) of the breast has become a cornerstone in advanced imaging, particularly for preoperative staging. Its use is supported by superior soft-tissue contrast and functional imaging capabilities that allow precise delineation of tumor boundaries, assessment of multifocal or multicentric disease, and evaluation of contralateral breast cancer [6]. Unlike mammography, which relies on tissue density differences, MRI leverages dynamic contrast-enhanced sequences to highlight vascular characteristics of tumors, thereby detecting cancers that might otherwise be missed, particularly in dense breasts [7]. These capabilities have raised interest in whether MRI could meaningfully refine surgical planning.

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Preoperative MRI demonstrates the highest sensitivity of all breast imaging modalities, with reported rates exceeding 90% for invasive cancers [8]. However, specificity is lower, with false positives ranging between 20–30% depending on the patient population [9]. This high sensitivity–specificity imbalance has been a central point in the controversy, as it may lead to unnecessary biopsies, patient anxiety, and potential overtreatment. Importantly, MRI often identifies additional foci of cancer not visible on mammography or ultrasound, which may alter the surgical plan from breast-conserving surgery (BCS) to mastectomy [10]. Whether these changes consistently benefit patients remains the subject of ongoing debate.

The use of MRI before surgery is not universally standardized and varies considerably across institutions and countries. European guidelines recommend preoperative MRI selectively, particularly for invasive lobular carcinoma, occult primary tumors, or in young women with dense breasts [11]. In contrast, the American Society of Breast Surgeons and the NCCN have taken a more cautious approach, emphasizing individualized use rather than routine application [12]. These differences in guideline recommendations reflect the lack of consensus in interpreting available evidence.

MRI also plays a role in evaluating response to neoadjuvant chemotherapy, where it is often considered the most reliable imaging modality for monitoring tumor shrinkage and predicting pathological complete response [13]. This application, while technically outside the immediate scope of surgical planning, reinforces the perception of MRI as an indispensable tool in comprehensive breast cancer care. Nonetheless, its preoperative utility must be assessed not only by its diagnostic superiority but also by its ability to improve surgical outcomes and long-term prognosis.

MRI And Its Impact On Breast-Conserving Surgery

Breast-conserving surgery (BCS), combined with adjuvant radiotherapy, has become the standard surgical approach for early-stage breast cancer due to its oncologic equivalence to mastectomy and superior cosmetic outcomes [14]. Achieving negative margins is essential in BCS, as positive or close margins are associated with higher local recurrence rates and the need for re-excisions. Preoperative MRI, with its superior sensitivity, has been proposed as a strategy to better define tumor extent, potentially reducing positive margins and reoperation rates [15].

Several studies have demonstrated that preoperative MRI identifies additional tumor foci in approximately 10–30% of patients initially considered suitable for BCS, leading to modifications in surgical planning [16]. These additional findings may expand the resection area or, in some cases, prompt conversion to mastectomy. While this could reduce the likelihood of incomplete excision, critics argue that MRI may also detect clinically insignificant lesions that would not have impacted prognosis, raising concerns about overtreatment [17].

A meta-analysis by Houssami et al. found that preoperative MRI was associated with a modest reduction in re-excision rates, though the benefit was inconsistent across studies [18]. Importantly, the

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COMICE trial, one of the largest randomized controlled studies on the subject, reported no significant reduction in reoperation rates when MRI was added to standard imaging [19]. This finding suggests that while MRI can provide more detailed tumor mapping, its routine use in all patients undergoing BCS may not consistently improve surgical outcomes.

The value of preoperative MRI may be greater in selected patient subgroups. For example, invasive lobular carcinoma, which often presents as a diffuse, infiltrative tumor difficult to assess on mammography or ultrasound, is more accurately visualized with MRI [20]. Similarly, in young women with dense breast tissue, MRI has demonstrated clear advantages in assessing tumor extent, thereby improving surgical planning [21]. These findings highlight the importance of tailoring MRI use to patient-specific factors rather than applying it universally.

Cosmetic outcomes also need to be considered in BCS. More extensive resections based on MRI findings may compromise aesthetic results without offering clear oncologic benefit [22]. Thus, the challenge lies in balancing the sensitivity of MRI with surgical judgment, ensuring that patients achieve both oncologic safety and acceptable cosmetic results. The integration of MRI findings into a multidisciplinary team discussion is essential to achieving this balance.

MRI In Reducing Positive Margins And Re-Excision Rates

One of the primary arguments in favor of preoperative MRI is its potential to reduce the incidence of positive surgical margins. A positive margin is a strong predictor of local recurrence and usually necessitates re-excision, leading to increased morbidity, cost, and patient distress [23]. MRI's ability to detect additional tumor foci and better delineate tumor boundaries suggests it could improve the completeness of excision, thereby reducing re-excision rates [24].

Evidence on this issue, however, has been mixed. Several retrospective studies have demonstrated that preoperative MRI significantly decreases the likelihood of positive margins and subsequent reoperations [25]. For instance, Fischer et al. reported that MRI-guided surgical planning reduced re-excision rates by up to 50% in certain cohorts [26]. Conversely, large randomized controlled trials, including the COMICE trial, failed to show a statistically significant reduction in re-excision rates with the addition of MRI to standard imaging [19]. This discrepancy underscores the complexity of translating imaging sensitivity into consistent surgical benefit.

The variability in outcomes may be explained by differences in surgeon expertise, MRI interpretation quality, and institutional protocols. In high-volume breast centers with experienced radiologists and surgeons, MRI appears to provide more reliable benefits in reducing margin positivity [27]. In contrast, centers with limited experience or without routine multidisciplinary integration may not realize the same advantages, leading to inconsistent results in multicenter trials [28].

Subgroup analyses suggest that certain populations derive greater benefit from MRI in reducing re-excision. Women with invasive lobular carcinoma, due to the infiltrative growth pattern, and younger

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women with dense breast tissue are particularly prone to underestimated tumor extent on conventional imaging, making MRI more valuable in these groups [20,21]. Moreover, multifocal and multicentric disease, which often requires wider resections, is more accurately detected by MRI, potentially avoiding inadequate excision and subsequent surgeries [29].

Despite potential benefits, there is also concern that MRI-driven expansions of surgical margins may paradoxically increase unnecessary removal of healthy tissue. Such overtreatment may compromise cosmetic outcomes without a proven survival advantage [30]. Hence, while MRI can reduce positive margins in selected patients, its widespread use for this purpose remains controversial, highlighting the need for personalized surgical planning.

Influence on mastectomy rates — are we overtreating?

The introduction of preoperative MRI coincided with reports of increased mastectomy use, raising concern that heightened sensitivity might prompt wider surgery without clear oncologic gain. Observational cohorts and institutional series have shown that MRI frequently uncovers additional ipsilateral foci or contralateral lesions that alter the operative plan from breast-conserving surgery (BCS) to mastectomy, yet this shift has not consistently translated into lower re-excision or recurrence rates in randomized data. The COMICE randomized trial notably failed to demonstrate a reduction in reoperation despite routine MRI, suggesting that a higher mastectomy rate may reflect precautionary escalation rather than objective need. These findings underpin a core surgical oncology question: does MRI-driven upstaging indicate biologically meaningful disease, or does it risk overtreatment? [10,18,19,30].

Multiple meta-analyses and guideline statements emphasize that while MRI detects additional disease, its impact on definitive surgical choice must be interpreted in clinical context. MRI can overestimate tumor extent due to background parenchymal enhancement, benign proliferative changes, or treatment-related effects, which may spur a transition to mastectomy without improving survival endpoints. EUSOBI and EUSOMA guidance therefore advocate selective rather than routine use, underscoring the importance of correlating MRI findings with targeted ultrasound and image-guided biopsy before altering the surgical plan. In practice, centers that embed MRI within multidisciplinary pathways report more judicious conversions to mastectomy, implying that process factors modulate how often “MRI-identified” disease justifiably escalates surgery. [11,12,18,27].

Patient subgroups particularly illustrate this tension. Invasive lobular carcinoma and very dense breasts are scenarios where MRI is more accurate than conventional imaging in mapping disease extent; in these patients, a higher mastectomy rate after MRI may be appropriate and reflect genuine multicentricity. Conversely, in average-risk, ductal histology with concordant conventional imaging, converting to mastectomy solely on MRI can be questioned unless additional foci are pathologically verified. Prior series demonstrate that MRI-detected secondary lesions influence surgical strategy most

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when they are biopsy-proven and spatially discordant from the index tumor, reinforcing that tissue confirmation is pivotal before abandoning BCS. [20,21,24,29].

The detection of occult contralateral cancers by MRI adds another layer. While contralateral MRI can identify synchronous malignancies that alter bilateral management, it also increases the detection of benign or indolent lesions, potentially nudging patients toward unilateral or bilateral mastectomy, including contralateral prophylactic mastectomy (CPM). The seminal NEJM study on contralateral screening MRI highlighted both the yield and the false-positive burden, underscoring the necessity of confirmatory biopsy and risk counseling rather than reflexive mastectomy. Ultimately, the aim is to prevent missed contralateral disease without inflating CPM absent proven survival benefit. [9,11,12].

Finally, aesthetic and quality-of-life outcomes must be weighed against theoretical oncologic advantages when mastectomy rates rise after MRI. Broader resections or mastectomy may compromise body image and necessitate more complex reconstruction, with downstream effects on recovery and satisfaction. Given randomized evidence showing no consistent reduction in re-excisions and no survival difference attributable to preoperative MRI in unselected populations, a calibrated approach is warranted: reserve MRI-driven escalation to mastectomy for biopsy-confirmed multifocal/multicentric disease, discordant imaging, lobular histology, or dense breasts where MRI meaningfully changes the therapeutic index. This strategy aligns with consensus statements cautioning against blanket MRI use and supports individualized, evidence-based surgical planning.

MRI For Contralateral Synchronous Cancer Detection

Preoperative MRI frequently includes evaluation of the contralateral breast, where its high sensitivity can reveal occult synchronous malignancies that are not detected by mammography or ultrasound. Seminal work from ACRIN 6667 demonstrated that contralateral MRI finds additional cancers at clinically meaningful rates in newly diagnosed patients, reshaping bilateral surgical planning in a subset. At the same time, the study highlighted a nontrivial false-positive burden, reinforcing that MRI-identified contralateral lesions warrant targeted second-look ultrasound and image-guided biopsy before any definitive change to surgical strategy. This duality—valuable detection versus potential overdiagnosis—underpins the selective, rather than routine, approach recommended by expert bodies. [9,11,12].

The clinical significance of MRI-detected contralateral disease depends on careful correlation with histopathology and patient risk profile. In average-risk patients, the absolute yield of clinically important contralateral cancers is modest and must be balanced against downstream biopsies and anxiety. In contrast, in high-risk cohorts—particularly carriers of BRCA1/2 or other pathogenic variants—MRI excels at identifying contralateral cancers earlier, often at smaller sizes and node-negative stages, enabling breast conservation or tailored bilateral strategies. Therefore, routine

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contralateral MRI may be most defensible in high-risk populations, whereas in unselected patients, a confirmatory-biopsy-first policy helps avoid unnecessary escalation to bilateral surgery. [9,11,31,32]. Guideline statements from European and North American societies converge on the principle that contralateral MRI findings should not drive mastectomy or contralateral prophylactic mastectomy (CPM) without tissue confirmation and multidisciplinary review. EUSOBI/EUSOMA guidance and the NCCN emphasize integrating MRI results with clinical exam and conventional imaging, then using targeted ultrasound and core biopsy to validate suspicious foci. This workflow preserves MRI's sensitivity while curbing overtreatment stemming from background parenchymal enhancement, benign proliferative changes, or atypical hyperplasia that may mimic carcinoma. In short, MRI should inform—but not dictate—contralateral surgical plans. [11,12,28].

From a patient-centered standpoint, detecting an occult contralateral cancer can substantially alter decision-making, reconstruction planning, and adjuvant therapy sequencing. Yet the psychological impact of false positives is real and may inadvertently nudge patients toward CPM despite limited survival benefit in average-risk settings. Shared decision-making that transparently conveys MRI's detection yield, positive predictive value, and the necessity of biopsy confirmation can temper reflexive bilateral surgery and align choices with oncologic risk rather than imaging anxiety. Embedding psycho-oncology support into the imaging-to-surgery pathway is a pragmatic adjunct to evidence-based practice. [9,11,12,18].

Finally, MRI's contralateral evaluation dovetails with broader risk-adapted screening paradigms. Decades of work in high-risk screening—such as studies by Kriege and Warner—established MRI's superiority over mammography alone in hereditary syndromes, lending biological plausibility to preoperative contralateral interrogation when genetic or familial risk is present. For surgical oncologists, this means calibrating the threshold for contralateral biopsy and bilateral surgery according to individual risk, histology, and radiologic-pathologic concordance, rather than adopting a one-size-fits-all approach. Such personalization maximizes benefit while minimizing harm. [31,32,33].

Subgroup Benefits — Dense Breasts, Invasive Lobular Carcinoma, And Young Women

Breast density significantly impacts the diagnostic performance of conventional imaging. Mammography sensitivity drops by nearly 50% in women with dense breast tissue, leading to underestimation of tumor size or even missed cancers. MRI, which does not rely on density differences but instead on vascular enhancement patterns, has demonstrated superior sensitivity in this population. Studies such as the DENSE trial showed that MRI screening in women with extremely dense breasts improves early detection, a principle that also extends to preoperative staging. For surgical oncologists, this means that preoperative MRI in dense breasts may provide a more accurate surgical roadmap, reducing the risk of underestimating tumor burden. [7,21,34].

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Invasive lobular carcinoma (ILC) poses unique diagnostic challenges due to its infiltrative, single-file growth pattern that rarely produces distinct masses on mammography or ultrasound. MRI has consistently outperformed conventional imaging in accurately mapping the extent of ILC, frequently uncovering multifocality and contralateral disease. Mann et al. demonstrated that preoperative MRI reduced re-excision rates and improved surgical planning in patients with ILC, supporting selective MRI use in this subgroup. Although not every ILC patient requires mastectomy, MRI findings often lead to wider resections or confirm the feasibility of breast conservation when conventional imaging appears equivocal. [20,35,36].

Young women with breast cancer also represent a group in whom preoperative MRI may be particularly useful. Their tumors tend to be biologically aggressive and occur more often in dense breasts, making conventional imaging less reliable. In this cohort, MRI not only enhances detection of multifocal disease but may also assist in surgical planning when fertility preservation, cosmesis, and psychosocial considerations carry substantial weight. Evidence suggests that preoperative MRI improves surgical accuracy in women under 40, although critics caution that younger patients may also be more vulnerable to overtreatment if MRI findings are not carefully validated with biopsy. [21,34,37].

Importantly, the benefits in these subgroups highlight the importance of **personalized imaging strategies**. Instead of applying preoperative MRI universally, tailoring its use to high-yield scenarios—dense breasts, lobular histology, and young patients—aligns with precision oncology principles. Such an approach maximizes diagnostic gain while minimizing unnecessary surgery, reinforcing the value of risk-adapted imaging integration in surgical oncology. [11,12,27].

COST-EFFECTIVENESS AND HEALTH POLICY IMPLICATIONS

The widespread use of preoperative MRI raises important questions about cost-effectiveness and healthcare resource allocation. MRI is significantly more expensive than mammography or ultrasound, with added costs from contrast agents, radiologist interpretation, and the downstream expenses of false-positive findings that lead to additional biopsies or surgeries. Given these financial implications, payers and health systems often scrutinize MRI utilization, particularly when its impact on long-term outcomes remains uncertain. In many countries, reimbursement policies restrict MRI use to defined high-risk groups or situations where conventional imaging is inconclusive. [38,39].

Economic modeling studies have yielded mixed results regarding the value of preoperative MRI. Analyses suggest that MRI is not cost-effective when applied universally to all breast cancer patients due to the modest reduction in re-excision rates and lack of survival benefit. However, cost-effectiveness improves when MRI is targeted to selected populations such as women with invasive lobular carcinoma, dense breasts, or hereditary cancer syndromes. These findings underscore the principle that patient selection is critical in maximizing clinical and economic benefit. [40,41].

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Health policy also varies considerably between regions. In Europe, MRI tends to be more readily incorporated into guidelines as an adjunct in complex cases, supported by EUSOBI and EUSOMA recommendations. In the United States, the National Comprehensive Cancer Network (NCCN) adopts a more cautious stance, reserving MRI for select indications rather than routine preoperative staging. This divergence reflects not only differences in healthcare funding but also cultural attitudes toward imaging, patient expectations, and medico-legal environments. [11,12,42].

Beyond direct costs, policy discussions increasingly account for indirect outcomes such as delays to surgery. MRI has been associated with longer diagnostic-to-treatment intervals due to scheduling bottlenecks, additional imaging, and biopsy procedures. Such delays, while often short, may heighten patient anxiety and in some cases interfere with timely initiation of systemic therapy. From a health-system perspective, balancing the diagnostic benefits of MRI against potential workflow inefficiencies is essential. Streamlined MRI pathways and integration into multidisciplinary clinics may mitigate these delays. [10,25,43].

Finally, global equity considerations must be acknowledged. Access to MRI is highly variable worldwide, with many low- and middle-income countries lacking infrastructure or trained personnel. Overemphasis on MRI in guidelines risks widening disparities if alternatives are not validated. Therefore, while MRI is valuable in select patients, policies should also support optimization of conventional imaging, investment in ultrasound expertise, and risk-adapted screening strategies to ensure equitable cancer care delivery. [38,44].

Conclusion And Future Directions

Preoperative breast MRI represents both a technological advance and a clinical dilemma in surgical oncology. Its unparalleled sensitivity allows detection of multifocal, multicentric, and contralateral cancers that may be underestimated by mammography or ultrasound. In selected patients—particularly those with dense breasts, invasive lobular carcinoma, or young age—MRI can refine surgical planning, reduce re-excisions, and provide a more accurate assessment of disease extent. However, evidence from randomized trials and meta-analyses shows that universal application does not consistently improve surgical or oncologic outcomes, raising concerns about overtreatment, increased mastectomy rates, and healthcare costs [10,18,19,30].

The controversies surrounding preoperative MRI highlight the need for a **personalized, risk-adapted approach** rather than routine use. Tailoring MRI to subgroups with demonstrable benefit aligns with precision oncology principles, while multidisciplinary evaluation and biopsy confirmation of MRI-detected lesions mitigate overtreatment risks. Such strategies ensure that the sensitivity of MRI is translated into clinically meaningful improvements without compromising cosmetic outcomes or increasing unnecessary mastectomies [11,12,20,36].

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Future research should focus on long-term outcomes of MRI-informed surgical decisions, including locoregional recurrence, survival, and patient-reported quality of life. While current evidence suggests no survival advantage in unselected populations, the potential for benefit in subgroups and in integration with molecular tumor profiling remains unexplored. Prospective trials that stratify patients by imaging phenotype, histology, and genomic risk may clarify where MRI confers durable oncologic benefit. Additionally, real-world data registries could provide insights into practice variability, cost-effectiveness, and patient-centered outcomes beyond controlled trial environments [38,40,43].

Emerging technologies may further enhance the value of preoperative MRI. Advances in functional imaging, such as diffusion-weighted imaging and radiomics, hold promise in improving specificity and reducing false positives. Artificial intelligence applications are being developed to refine lesion characterization and integrate imaging with genomic and clinical data, potentially moving toward fully personalized surgical planning. These innovations, coupled with minimally invasive localization techniques, could expand MRI's role from diagnostic adjunct to integral part of precision breast surgery [6,39,44].

In conclusion, preoperative MRI is a powerful tool that should be viewed as complementary rather than universal in breast cancer management. Its role is best defined by careful patient selection, multidisciplinary collaboration, and ongoing evaluation of both clinical and economic outcomes. The future lies not in blanket adoption but in strategic, evidence-based integration of MRI into the evolving landscape of breast surgical oncology. [12,18,27,42].

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