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The Additional Diagnostic Value of Mri in Mammographic Screening

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Abstract: Breast cancer remains one of the leading oncological causes of morbidity and mortality among women worldwide, making early detection a key priority of modern healthcare systems. Population-based mammographic screening is widely used as the primary diagnostic approach; however, its effectiveness may decrease in women with dense breast tissue and in diagnostically complex situations.

The present study aimed to assess the practical contribution of magnetic resonance imaging (MRI) as an additional diagnostic method within an organized mammographic screening program. The analysis included screening data of more than 100,000 women aged 40–69 years examined between 2022 and 2024. In cases with suspicious mammographic findings, further evaluation using ultrasonography and contrast-enhanced MRI was performed.

Breast cancer was confirmed in 111 women (0.11%), with early-stage disease (I–II) identified in 65.2% of cases. The inclusion of MRI significantly improved diagnostic sensitivity, reaching 95–98%, particularly in patients with dense glandular breast tissue. The findings indicate that MRI provides meaningful additional diagnostic information and should be considered a selective complementary method rather than a routine screening tool.

Keywords: breast cancer; screening diagnostics; mammography; magnetic resonance imaging; dense breast tissue; early detection.

INTRODUCTION

Breast cancer represents a major public health challenge and accounts for a substantial proportion of oncological diseases among women. Despite advances in treatment, mortality remains high when the disease is diagnosed at advanced stages. Therefore, early detection before the appearance of clinical symptoms is widely recognized as the most effective strategy to reduce breast cancer–related mortality.

Mammographic screening has been implemented in many countries as a cost-effective and accessible population-based diagnostic method. Its main advantage lies in the ability to detect microcalcifications and early structural changes that may not be clinically apparent. Numerous studies have demonstrated that regular participation in screening programs leads to a higher proportion of cancers detected at early stages and a measurable reduction in mortality rates.

At the same time, clinical experience shows that mammography is not universally sufficient. Its diagnostic sensitivity decreases in women with dense breast tissue, multifocal growth patterns, and certain non-invasive or early invasive tumor forms. Under such conditions, the true extent of pathological changes may be underestimated, potentially affecting treatment planning.

Magnetic resonance imaging has emerged as a highly informative diagnostic modality due to its excellent soft-tissue contrast and independence from breast tissue density. Unlike mammography, MRI allows functional assessment of tumor vascularity through contrast enhancement dynamics. In recent years, the role of MRI as an adjunctive diagnostic tool has gained increasing attention, particularly for high-risk patients and diagnostically ambiguous cases.

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In this context, evaluating the real clinical value of MRI within an organized mammographic screening framework is of practical importance, especially under the healthcare conditions of the

Republic of Uzbekistan. MRI provides higher accuracy in assessing the true size and extent of invasive breast tumors.

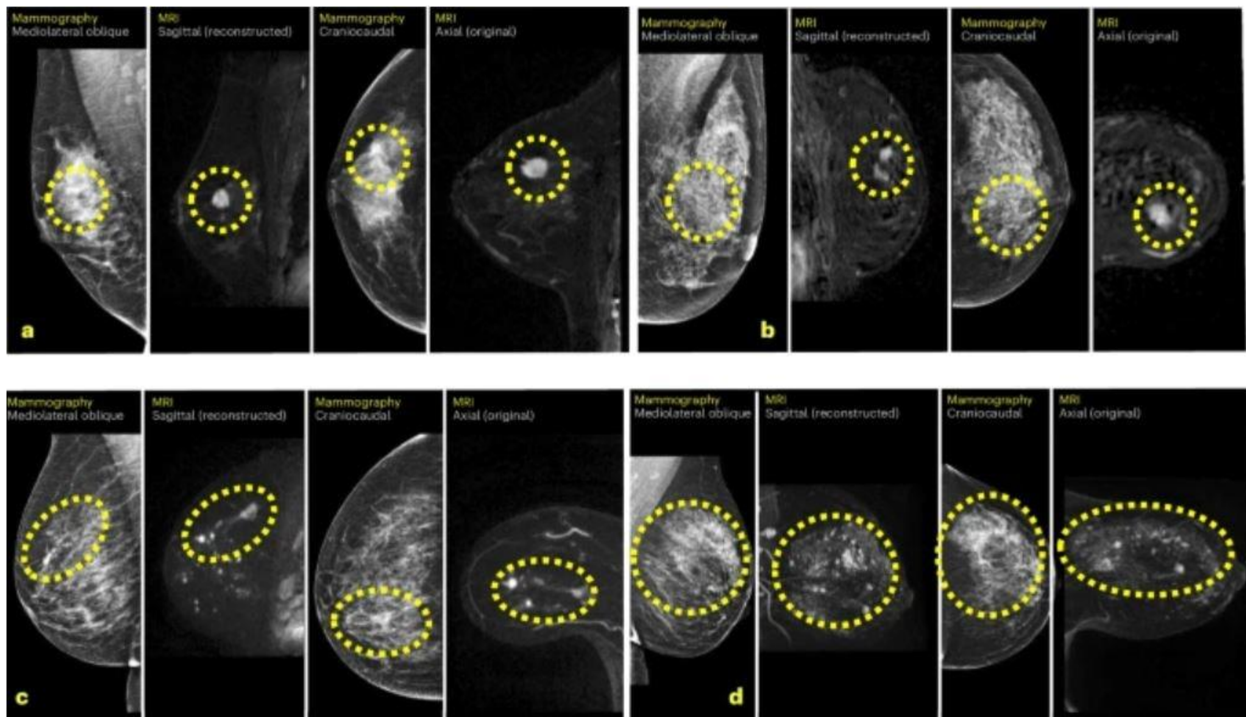

Figure 1. Comparative visualization of breast tumors on mammography and magnetic resonance imaging (MRI). Lesions marked with yellow dashed lines are partially detected on mammography, whereas MRI provides more precise visualization of tumor size and extent.

Analysis of the literature indicates that mammographic screening remains the primary method for early detection of breast cancer. However, MRI significantly improves diagnostic accuracy in high-risk patients, women with dense breast tissue, and in complex clinical cases. Therefore, the use of MRI as a selective complementary modality to mammographic screening is scientifically justified.

MATERIALS AND METHODS

This study was a retrospective, observational scientific and practical investigation conducted within the framework of a population-based mammographic screening program between 2022 and 2024. Women aged 40–69 years were selected as the study population. In total, more than 100,000 women underwent mammographic screening, and those with suspicious or pathological findings were referred for further in-depth diagnostic examinations.

The study was carried out in accordance with the screening protocols adopted within the healthcare system of the Republic of Uzbekistan.

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Figure 2. Optimal workflow of the mammographic examination process in a breast screening center. The infographic illustrates the stages of patient registration, examination, analysis of results, patient notification, and monitoring of screening effectiveness. This approach contributes to the standardization of the screening process and enhances diagnostic efficiency.

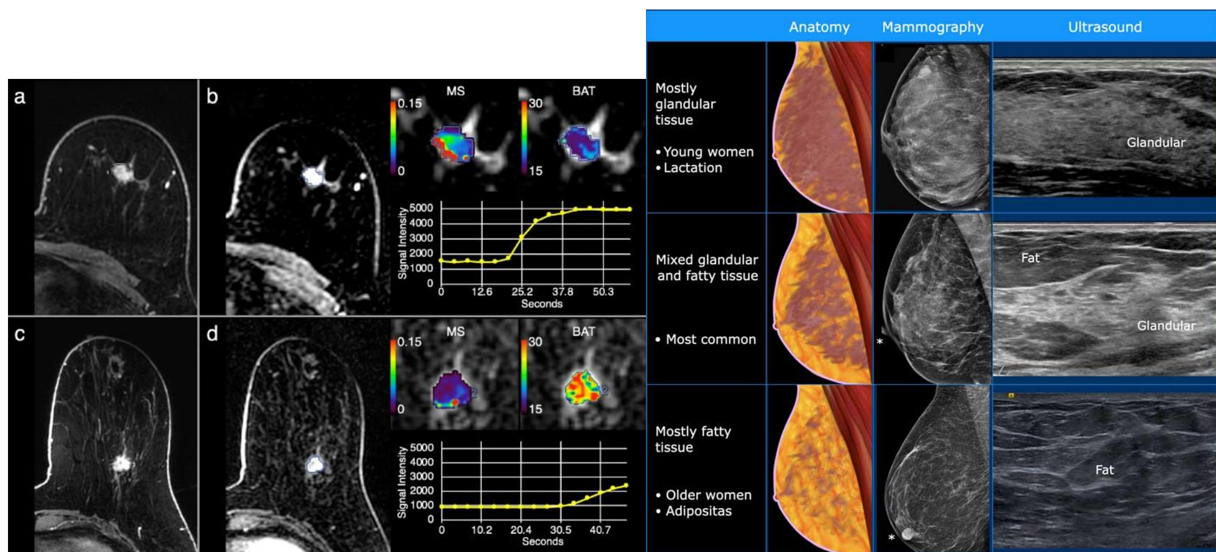

Figure 3. Comparative presentation of the diagnostic capabilities of mammography, ultrasonography, and dynamic contrast-enhanced magnetic resonance imaging (MRI) depending on breast tissue composition and tumor characteristics. In dense glandular breast tissue, the sensitivity of mammography decreases, whereas ultrasonography and MRI provide additional diagnostic value. Dynamic contrast-enhanced MRI demonstrates rapid signal intensity increase and subsequent “wash-out” kinetics, which are characteristic features of malignant lesions.

Inclusion and Exclusion Criteria

Inclusion criteria: female sex; age range 40–69 years; participation in the population-based mammographic screening program.

Exclusion criteria: previously confirmed breast cancer; ongoing oncological treatment; contraindications to magnetic resonance imaging (presence of metallic implants, cardiac pacemakers, intolerance to contrast agents, and other related conditions).

Mammographic Examination Methodology

All patients underwent digital two-view mammography performed in craniocaudal (CC) and mediolateral oblique (MLO) projections. Examinations were conducted using modern digital mammography systems with low-dose ionizing radiation.

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Mammographic images were analyzed for the presence of the following features: microcalcifications, architectural distortions, and focal densities. The obtained results were assessed according to the international BI-RADS (Breast Imaging Reporting and Data System) classification, using categories ranging from 0 to 6.

Ultrasonographic Examination (US)

Ultrasonographic examination was performed in women with dense breast tissue (ACR C–D) as well as in cases with indeterminate or suspicious findings on mammography. The examination was carried out using high-frequency linear transducers.

Ultrasonography played an important role in:

differentiating solid and cystic lesions;

assessing the predominance of glandular tissue in younger women;

providing accurate guidance for biopsy procedures.

Ultrasonographic findings were compared with mammographic results and were used to refine and confirm the final diagnosis.

MRI Examination Methodology:

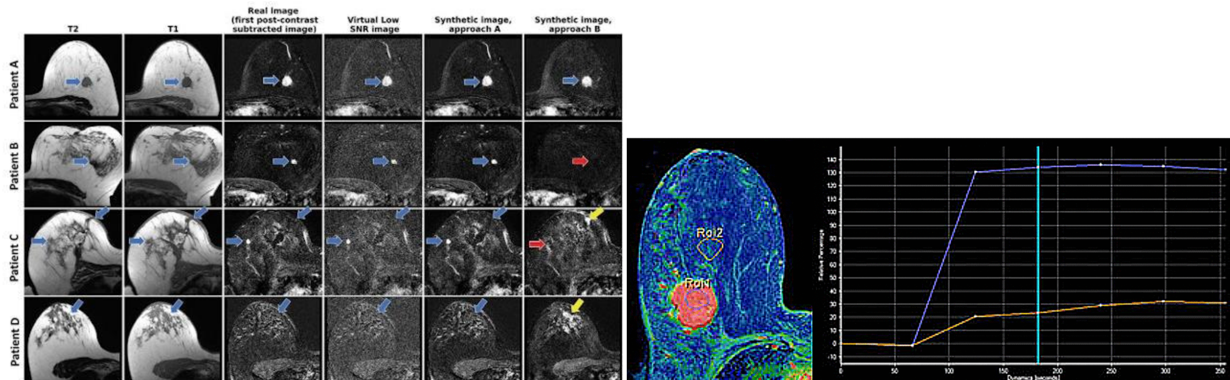

Figure 4. Visualization of breast tumor lesions on real and synthetic magnetic resonance imaging (MRI) images, along with the results of dynamic contrast-enhanced analysis. Rapid increase in signal intensity followed by a “wash-out” pattern is characteristic of malignant processes and contributes to improved diagnostic accuracy of MRI.

Breast magnetic resonance imaging was performed in patients with suspicious findings on mammography and ultrasonography, as well as in individuals belonging to high-risk groups. MRI examinations were conducted using a 1.5 Tesla magnetic resonance scanner without ionizing radiation, equipped with a dedicated breast coil.

All examinations were performed with the administration of a contrast agent. A gadolinium-based contrast medium was intravenously injected at a dose of 0.1 mmol/kg body weight using an automatic injector.

The MRI protocol included the following sequences:

T1-weighted and T2-weighted images;

fat-suppressed sequences;

dynamic contrast-enhanced phases (early, peak, and delayed phases).

Images were acquired with a slice thickness of 3–4 mm. Dynamic contrast enhancement analysis was applied to assess “wash-in” and “wash-out” curves, tumor vascular characteristics, and the presence of multifocal and multicentric disease.

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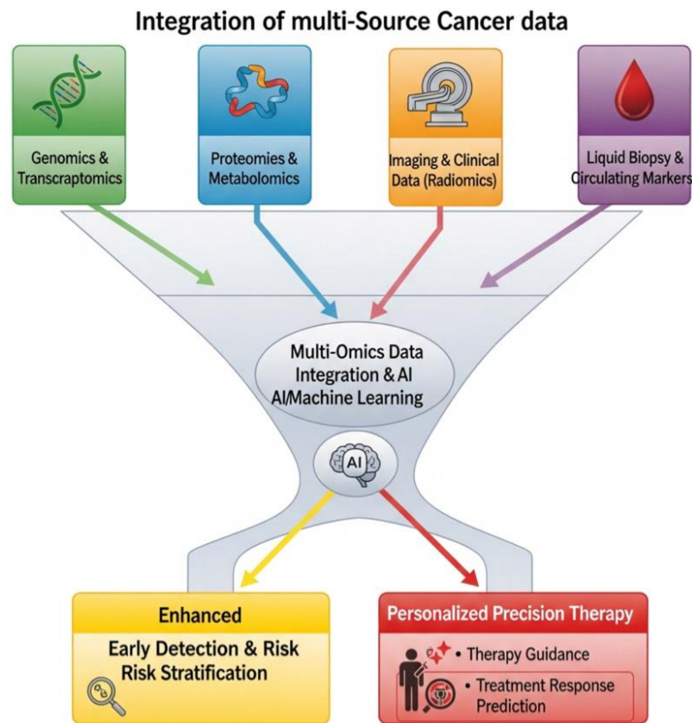

Figure 5. Multisource integration of oncological data (genomics, proteomics, radiomics, and liquid biopsy) using artificial intelligence and machine learning approaches, enabling early detection, risk stratification, and the development of personalized precision treatment strategies.

In this study, the following stepwise diagnostic algorithm was applied:

Mammography — the primary screening stage;

Ultrasonography (US) — in women with dense breast tissue and in cases with suspicious findings;

Magnetic resonance imaging (MRI) — in high-risk patients and in complex clinical cases.

This approach contributed to increased diagnostic sensitivity, reduction of false-positive results, and optimization of treatment planning. The integrated diagnostic strategy improved overall diagnostic accuracy and played an important role in determining appropriate therapeutic management.

STATISTICAL ANALYSIS

The collected data were statistically analyzed using Microsoft Excel and SPSS Statistics version 26.0. Categorical variables were expressed as absolute and relative values (percentages). The χ^2 (chi-square) test was used to compare the diagnostic performance of different imaging modalities. Differences between results were considered statistically significant at $p < 0.05$. Based on the statistical analysis, the diagnostic sensitivity of mammography, ultrasonography, and magnetic resonance imaging was evaluated.

RESULTS

Mammographic Screening Outcomes

During the study period from 2022 to 2024, more than 100,000 women aged 40–69 years underwent population-based mammographic screening. Patients in whom suspicious or pathological findings were identified on mammographic images were referred for further in-depth diagnostic examinations.

As a result of the conducted examinations, breast cancer was confirmed in a total of 111 cases, representing 0.11% of the screened population. The majority of detected cases were diagnosed at early stages of the disease, indicating the high clinical effectiveness of mammographic screening.

These findings confirm the high efficiency of population-based mammographic screening in the early detection of breast cancer.

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Distribution of Breast Cancer by Stage

The stage distribution of the 111 confirmed breast cancer cases was analyzed. The results are presented in Table 1.

Table 1. Distribution of detected breast cancer cases by disease stage

Stage	Number of cases	Percentage, %
Stages I–II	75	65,2
Stages III–IV	36	34,8
Total	111	100

As shown in the table, 65.2% of the detected cases were diagnosed at stages I–II, clearly demonstrating the preventive significance of population-based screening programs. In populations not covered by screening, the proportion of advanced-stage disease has been reported in the literature to exceed 50–60%, whereas in the present study this proportion was markedly lower.

A comparative analysis of the detection performance of mammography, ultrasonography, and magnetic resonance imaging (MRI) was conducted. The detection rates and key diagnostic capabilities of each imaging modality were evaluated.

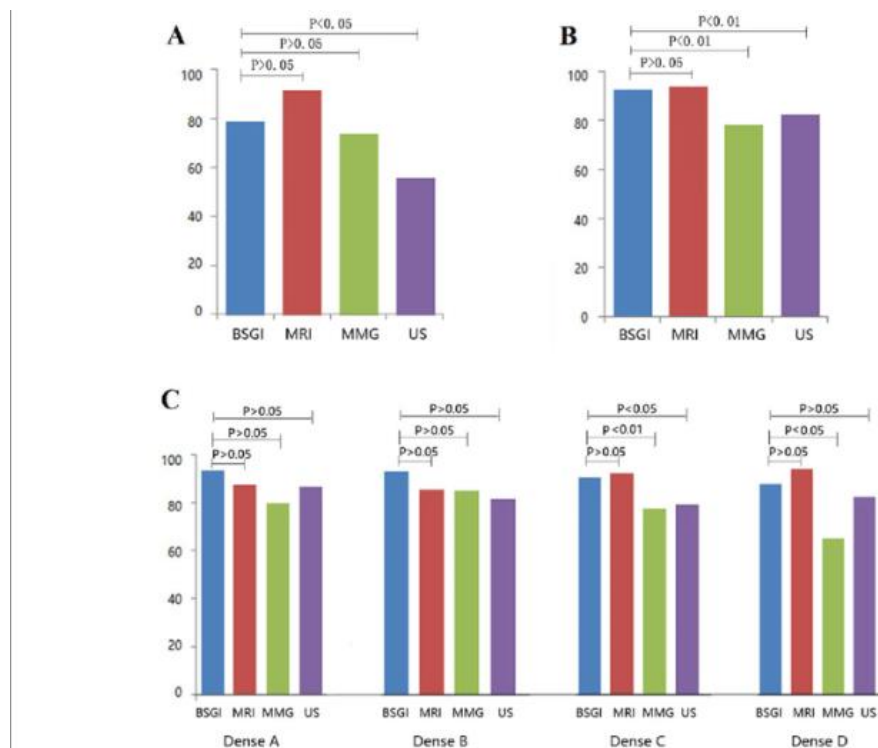

Figure 6. Comparative analysis of the diagnostic performance of different imaging modalities, including breast-specific gamma imaging (BSGI), magnetic resonance imaging (MRI), mammography (MMG), and ultrasonography (US). Panels (A, B) present diagnostic sensitivity in the general population, while panel (C) compares the performance of these modalities according to breast density categories (ACR Dense A–D). MRI and BSGI demonstrated higher diagnostic accuracy, particularly in dense breast tissue, showing statistically significant superiority over mammography ($p < 0.05$; $p < 0.01$).

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Table 2. Comparative analysis of imaging modalities demonstrated the following results:

Diagnostic modality	Detection rate	Main advantage
Mammography	≈ 85 %	Microcalcifications, screening
Ultrasonography (US)	≈ 70 %	Dense breast tissue, cystic/solid lesion differentiation
Magnetic Resonance Imaging (MRI)	≈ 95–98 %	Multifocal tumors, invasive disease

MRI demonstrated the highest diagnostic sensitivity compared with mammography and ultrasonography. In particular, MRI enabled the detection of small invasive tumors, as well as multifocal and multicentric lesions that were not identified on mammography.

Additional Diagnostic Findings Detected by MRI

MRI examinations revealed several clinically significant additional diagnostic findings. Specifically, multifocal tumor processes that were not detected by mammography or ultrasonography were identified in 12 patients. In addition, occult pathological lesions in the contralateral breast were detected in 5 patients, which had not been identified during the initial diagnostic workup.

Assessment of the true extent of tumor spread using MRI led to changes in surgical treatment strategy in 20 patients, including a shift from planned sectoral resection to more extensive surgical intervention.

Dynamic contrast-enhanced analysis demonstrated rapid contrast uptake followed by rapid "wash-out" in malignant lesions, whereas benign processes were characterized by slower and more homogeneous contrast enhancement. These findings confirm the superiority of MRI in differential diagnosis.

Effectiveness of MRI in Women with Dense Breast Tissue

In women with dense breast tissue (ACR C–D), a reduction in mammographic sensitivity was observed. In this patient group, the use of MRI enabled highly accurate detection of small invasive carcinomas and occult structural abnormalities.

The results indicate that MRI significantly improves diagnostic accuracy in patients with dense breast tissue and contributes to an increased rate of early detection.

Results of an Integrated Diagnostic Approach

An integrated diagnostic approach combining mammography, ultrasonography, and MRI increased the proportion of early-stage diagnoses, improved surgical planning, and reduced unnecessary invasive procedures.

DISCUSSION

The results of this study confirm the high effectiveness of organized mammographic screening in detecting breast cancer at early stages. More than sixty-five percent of confirmed cases were diagnosed at stages I–II, which highlights the preventive potential of systematic screening programs. Compared with populations lacking structured screening, where advanced stages often predominate, these findings demonstrate a clear diagnostic advantage.

At the same time, the study revealed the limitations of mammography in specific patient groups. In women with dense breast tissue, a noticeable reduction in diagnostic sensitivity was observed. This finding is consistent with international data and explains the necessity of additional imaging methods in selected cases.

Magnetic resonance imaging showed the highest diagnostic sensitivity among the evaluated modalities. MRI was particularly valuable in identifying small invasive tumors, multifocal and multicentric lesions, as well as occult contralateral abnormalities that were not detected by

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mammography or ultrasonography. Importantly, MRI findings influenced clinical decision-making, including modification of surgical strategies in a considerable number of patients.

From a practical standpoint, MRI should not be interpreted as a replacement for mammographic screening. Its higher cost, limited availability, and risk of false-positive results restrict its use as a universal screening method. However, when applied selectively—based on breast density, risk factors, or inconclusive primary imaging—MRI significantly enhances overall diagnostic accuracy.

Thus, a stepwise diagnostic approach combining mammography, ultrasonography, and MRI appears to be the most rational strategy. Such integration allows balanced use of resources while maximizing early detection and optimizing treatment planning.

CONCLUSION

The conducted analysis demonstrates that population-based mammographic screening remains the cornerstone of early breast cancer detection. Screening of more than 100,000 women resulted in the identification of breast cancer in 0.11% of cases, with a predominance of early-stage disease, confirming the clinical and preventive value of this approach.

Magnetic resonance imaging provides substantial additional diagnostic information when used as a complementary method. Its high sensitivity, particularly in women with dense breast tissue, allows more accurate assessment of tumor extent and contributes to improved surgical planning. Nevertheless, due to economic and practical limitations, MRI cannot be recommended as a primary screening modality for the general population.

Under the conditions of the Republic of Uzbekistan, further development of mammographic screening programs combined with selective use of MRI represents an effective and scientifically justified strategy for improving breast cancer diagnostics and patient outcomes.

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