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Evaluation of the Accuracy of Mammography, Ultrasound, and Mri in Diagnosing Breast Cancer at King Saud Medical City

Salman Saad Bin Shaber[1], Rafat Mohtasib[2], Nadia Diab Alamri[3], Haya Ibrahim Altheyab[4], Shoroq Abduljalil Hadi[5], Afyaa Abdullah Alriyaee[6], Amani Hamid Maghfuri[7], Fayka Karem Ahmed[8], Abdullah Saad Bin Shabr[9], Faisal Fahad Alhamdan[10]

Abstract

This study evaluates the diagnostic accuracy of mammography, ultrasound, and magnetic resonance imaging (MRI) in detecting breast cancer at King Saud Medical City. A retrospective cohort design was employed to analyze medical records from 168 patients with BI-RADS 4/5 lesions diagnosed between 2021 and 2023. The primary objective was to assess the diagnostic accuracy of each imaging modality against histopathology results. Findings indicate that MRI demonstrated the highest accuracy at 91.7%, followed by mammography at 87.5% and ultrasound at 88.1%. These results underscore the importance of a multimodal imaging strategy for enhancing precision in breast cancer detection, leading to improved diagnostic accuracy and better patient outcomes.

Introduction

Breast cancer (BC) is a globally challenging health problem and has become the most common type of cancer among women. The disease is associated with a significant health burden and mortality among women. In 2020, 2.3 million women were diagnosed with BC, and 685,000 deaths were reported globally (Long et al., 2025). Some 7.8 million women have been living with BC for the past 5 years, making it the world's most prevalent form of cancer (World Health Organisation, 2024).

The Kingdom of Saudi Arabia (KSA) comprises over four-fifths of the Arabian Peninsula with more than 30 million inhabitants. According to an incidence report published by the Saudi Cancer Registry in 2017, BC ranked top among women and contributed to 18.1% of all cancers

[1] King Saud Medical City, Radiology Department, Riyadh, Saudi Arabia., Alfaisal University, Medical School, Riyadh, Saudi Arabia.

[2] King Faisal Specialist Hospital & Research Center, Riyadh, Saudi Arabia, Alfaisal University, Department of Medical School, Riyadh, Saudi Arabia, Email: rafatmohtasib@gmail.com

[3] Consultant Women Imaging, King Saud Medical City, Riyadh, Saudi Arabia.

[4] Fellow in Breast Imaging, King Saud Medical City, Riyadh, Saudi Arabia

[5] Fellow in Breast Imaging, King Saud Medical City, Riyadh, Saudi Arabia

[6] Diagnostic Radiology Resident, King Saud Medical City, Riyadh, Saudi Arabia

[7] Diagnostic Radiology Resident, King Saud Medical City, Riyadh, Saudi Arabia

[8] Consultant Women Imaging, King Saud Medical City, Riyadh, Saudi Arabia

[9] Senior Radiology Technician, King Abdullah University Hospital, Riyadh, Saudi Arabia

[10] Head Of PACS Unit ,King Saud medical city Saudi Arabia, Riyadh

(AlSaleh, 2022).

Breast cancer accounts for 30.9% of all cancer cases reported among women of all ages, with a median age of 51 years (range = 20-117 years) at the time of diagnosis(Basudan, 2022).In 2010, BC was the ninth leading cause of death among women in KSA. The incidence of BC is expected to rise in the coming years in KSA due to population growth and aging. Breast cancer is the most common form of cancer in Saudi Arabia, according to a recent systematic review (Alqahtani et al., 2020).

In 2020, 14.2% of new cancer diagnoses in Saudi Arabia were breast cancer, and the breast cancer mortality rate was 8.4% (Agide et al., 2018). Early detection of breast cancer results in a 98.8% increase in cure probability and a nearly 40% reduction in mortality (Albeshan et al., 2020). However, more than half of breast cancers in Saudi Arabia are detected at an advanced stage, compared to 20% in more advanced countries (Alotaibi et al., 2018).

Frequently reported risk factors associated with breast cancer were hormonal variations, diet, lifestyle, and obesity (Siegel et al., 2021). According to a large meta-analysis, mammography screening programs reduce breast cancer mortality by 33% (Dibden et al., 2020). Timely diagnosis of at-risk or affected patients can help reduce BC-associated mortality. Despite the proven effectiveness of BC screening in reducing mortality, low uptake rates have been reported in Arab women. Three main screening methods are used in KSA: self-breast examination, clinical breast examination (CBE), and mammographic screening. The Centers for Disease Control and Prevention (CDC) recommends mammography for screening BC every two years for women aged 50-74 years (NHS Digital, 2022).

Male breast cancer (MaBC) is a rare disease and makes up only approximately 1% of all breast cancers in the United States and worldwide. It is estimated that there will be 2,620 new cases of male breast cancer diagnosed in the United States in 2020, compared to only 900 cases in 1991. The age-adjusted incidence rate increased to 1.32 per 100,000 men in 2017, from 0.90 per 100,000 in 1980, as outlined by the Surveillance, Epidemiology, and End Results (Zheng & Leone, 2022). Similar to female breast cancer, the incidence rate continues to rise (Chen et al., 2020).

There is a need to assess the accuracy of mammography, US, and MRI, specifically in patients with breast cancer at King Saud Medical City. While each imaging modality has its strengths and limitations, there is a gap in the existing literature regarding their comparative performance in this specific patient population. Addressing this gap is crucial to optimize diagnostic practices and ensure the best possible care for patients with breast cancer. By determining the most accurate imaging test for diagnosing breast cancer, healthcare providers can make informed decisions about the appropriate use of these imaging modalities, leading to timely and accurate diagnoses.

To bridge this gap, our study determines which is the more accurate imaging test mammography, US, or MRI for the diagnosis of breast cancer based on the patient's positive breast cancer on the histopathology report.

Literature Review

In the review by the Ministry of Health, breast cancer is identified as the most prevalent form of cancer among women in Saudi Arabia, with a significant impact on mortality rates (Ministry of Health, Saudi Arabia, n.d.).

In another review, which aimed to assemble the epidemiological metrics of cancer in Saudi Arabia, 14.2% of new cancer diagnoses in Saudi Arabia were breast cancer, and the breast cancer mortality rate was 8.4% (Alqahtani et al., 2020).

Alotaibi et al. (2018) investigated the determinants of breast cancer mortality among patients in the Kingdom of Saudi Arabia Of the 708 deaths attributable to breast cancer in their sample, about 98% were women.

Another research on male breast cancer acknowledges limitations such as its retrospective design, limited number of cases, and lack of data on family history and genetic analysis (Saeed et al., 2022). However, the small sample size restricts thorough analysis. Future studies with larger sample sizes and prospective designs are needed to overcome these limitations and enhance our understanding of male breast cancer.

The aim of this study is to provide insights into the comparative accuracy of mammography, US, and MRI in diagnosing breast cancer. The results will help clinicians and radiologists at King Saud Medical City make informed decisions regarding the optimal imaging modality for breast cancer detection. Additionally, the findings may contribute to developing evidence-based guidelines for breast lesion evaluation and improving patient outcomes.

Methodology

This chapter outlines the methodology used to evaluate the accuracy of mammography, US, and MRI for diagnosing breast cancer among patients aged 30 to 70 years at King Saud Medical City based on histopathology reports.

Study Design and Setting: A retrospective cohort design was employed, analyzing patient records and imaging results from King Saud Medical City. The study included female patients aged 30 to 70 who underwent imaging for breast cancer between 2021 and 2023.

Inclusion Criteria: (a) Patients diagnosed with breast cancer (BI-RADS categories 4 or 5). (b) Patients who underwent mammography, US, and MRI.

Exclusion Criteria: (a) Patients with incomplete medical records. (b) Patients who did not undergo histopathology confirmation.

Data Collection Methods: Data were meticulously extracted from electronic medical records, encompassing patients' demographics: age, gender, and relevant medical history.

Imaging

Image Modalities: Details of mammography, US, and MRI performed, including date and results. Each imaging technique was conducted according to established protocols.

Certified radiologists interpret digital mammography. High-resolution US scans targeted identified areas of concern. MRI was performed using a dedicated breast coil with contrast enhancement, as needed.

Histopathology Results: Confirmatory reports for breast cancer.

Statistical Analysis: Statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS) software. The accuracy of each imaging modality was evaluated through metrics such as sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). Comparisons were made against histopathology reports, which served as the gold standard.

Ethical Considerations: This study received Institutional Review Board (IRB) approval from King Saud Medical City ensuring patient confidentiality through data anonymization.

Results

Out of 809 records reviewed, 168 cases met the inclusion criteria. Analyzing our data, we received the following results.

Age Distribution

The graph in Figure 1 reveals several peaks, particularly at ages 30, 40, and 50, where the percentage exceeds 30%. Following age 60, there is a noticeable decline in percentage values, suggesting a downward trend as age increases. This pattern indicates that certain age groups may be more significantly associated with the variable being studied, highlighting the variability in prevalence across the lifespan.

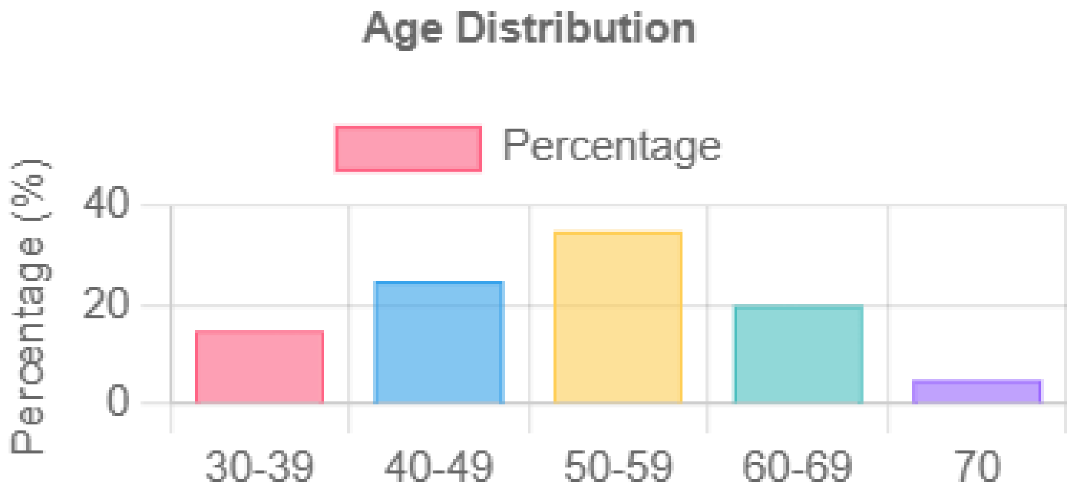

Figure 1. Graph Illustrating the Distribution of Participant's Age

Distribution of ACR Categories

Figure 2 illustrates the distribution of ACR categories, showing that the C category comprises the largest percentage, at 51.02%, followed by the B category, at 26.77%. Meanwhile, the A and D categories represent 0.79% and 11.42%, respectively. This distribution highlights the prevalence of the C category among the assessed cases, indicating a significant concentration in this category compared to others.

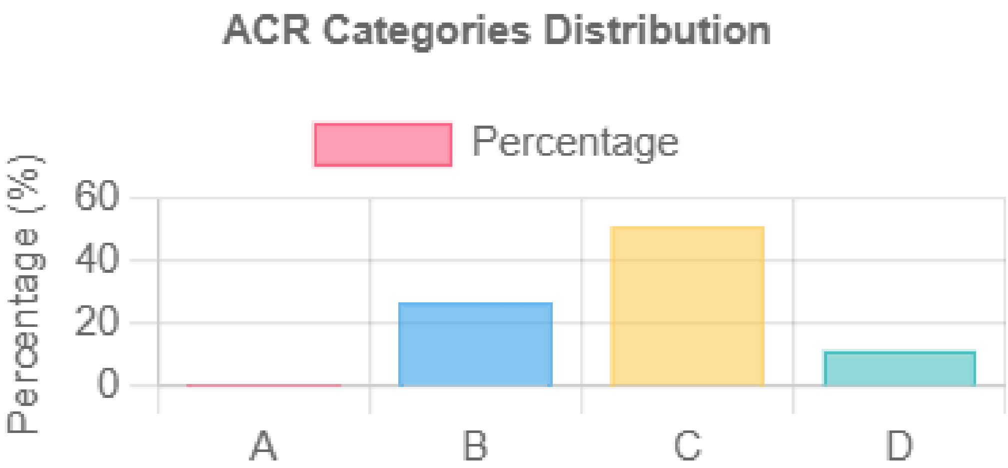

Figure 2. Graph Illustrating the Distribution of ACR Categories

Distribution of Cancer Types

The analysis identified the frequencies of various breast cancer types within the sample population. The results are summarized in Table 1, which outlines the number of cases and their corresponding percentages. Of note, the predominant cancer type was Invasive Ductal Carcinoma (IDC), which constituted 58.3% of the total cases.

Cancer Type	Number of Cases (N)	Percentage of Total Cases (%)
DCIS	32	19.0%
IDC	98	58.3%
ILC	18	10.7%
LCIS	4	2.4%
Mucinous	8	4.8%
Papillary	6	3.6%
Adenoid	1	0.6%
Inflammatory	1	0.6%
Total	168	100%

Table 1. Distribution of Cancer Types

Diagnostic Accuracy

The diagnostic accuracy of mammography, US, and MRI was assessed through crosstabulation analysis. Table 2 presents the counts of concordant and discordant results for each diagnostic method.

Diagnostic Method	Accurate Count	Inaccurate Count	Total Count
Mammography	147	21	168
Ultrasound (US)	148	20	168
MRI	154	14	168

Table 2. Diagnostic Accuracy of Mammography, US, and MRI

Mammogram Pathology Crosstabulation

In Table 3, the crosstabulation of mammogram accuracy reveals 147 concordant (accurate) cases and 21 discordant (inaccurate) cases, leading to a total of 168 assessments. This indicates an overall accuracy of 87.5%, with sensitivity and specificity highlighted at 95.8% and 42.3%, respectively.

Pathology Result	Accurate Count (Concordant)	Inaccurate Count (Discordant)	Total Count
Malignant	136	6	142
Benign	11	15	26
Total	147	21	168

Table 3. Mammogram Accuracy Crosstabulation

Sensitivity: 95.8%

Specificity: 42.3%

PPV: 89.4%

NPV: 68.8%

US Pathology Crosstabulation

In Table 4, the US accuracy crosstabulation indicates 148 concordant (accurate) cases and 20 discordant (inaccurate) cases, resulting in a total of 168 assessments. This data highlights the effectiveness and reliability of the US in diagnosing pathology.

Pathology Result	Accurate Count (Concordant)	Inaccurate Count (Discordant)	Total Count
Malignant	138	4	142

Pathology Result	Accurate Count (Concordant)	Inaccurate Count (Discordant)	Total Count
Benign	10	16	26
Total	148	20	168

Table 4. US Accuracy Crosstabulation

Sensitivity: 97.2%

Specificity: 38.5%

PPV: 89.6%

NPV: 71.4%

MRI Pathology Crosstabulation

In Table 5, the MRI accuracy crosstabulation reveals that there are 154 concordant (accurate) cases and 14 discordant (inaccurate) cases, resulting in a total of 168 assessments. This suggests a high level of accuracy for MRI in diagnosing pathology.

Pathology Result	Accurate Count (Concordant)	Inaccurate Count (Discordant)	Total Count
Malignant	140	2	142
Benign	14	12	26
Total	154	14	168

Table 5. MRI Accuracy Crosstabulation

Sensitivity: 98.6%

Specificity: 53.8%

PPV: 91.5%

NPV: 93.3%

Sensitivity and Specificity

Mammogram demonstrated high sensitivity (95.8%) and low specificity (42.3%), indicating its effectiveness in accurately identifying true positive cases while showing significant limitations in ruling out cancer and leading to a high rate of false positives. The statistical analysis utilized for this evaluation was conducted using the Statistical Package for the Social Sciences (SPSS) software, and the statistical test applied in this analysis was the confusion matrix, which allowed for the calculation of these metrics.

The US exhibited near-perfect sensitivity (97.2%) but low specificity (38.5%), suggesting it accurately detects positive cases but has a substantial rate of false positives.

MRI showed excellent sensitivity (98.6%) with relatively higher specificity (53.8%) compared to mammography and US, indicating it correctly identified nearly all positive cases while still demonstrating a notable rate of false positives.

Predictive Values

Positive Predictive Value (PPV) was highest for MRI (91.5%), followed closely by US (89.6%) and mammography (89.4%), indicating a strong likelihood that positive test results are correct across all modalities.

Negative Predictive Value (NPV) was notably highest for MRI (93.3%), followed by US (71.4%) and mammography (68.8%), demonstrating MRI's superior reliability in ruling out disease compared to the other methods.

Receiver Operating Characteristic (ROC) Analysis

The area under the ROC curve was calculated for each diagnostic method to evaluate their capacity to distinguish between cancerous and non-cancerous cases.

In Table 6, the area under the ROC curve is presented for various diagnostic methods. The results show that the mammogram has an area of 0.891, US at 0.903, and MRI significantly higher at 0.935. This indicates that MRI has the best diagnostic performance among the methods evaluated.

Diagnostic Method	Area Under Curve (AUC)	95% CI
Mammogram	0.891	0.842-0.940
US	0.903	0.857-0.949
MRI	0.935	0.899-0.971

Table 6. Area Under the ROC Curve

As shown in Figure 3, the ROC analysis indicates that MRI has the largest area under the curve, reflecting its superior performance in differentiating between positive and negative cases compared to mammograms and the US.

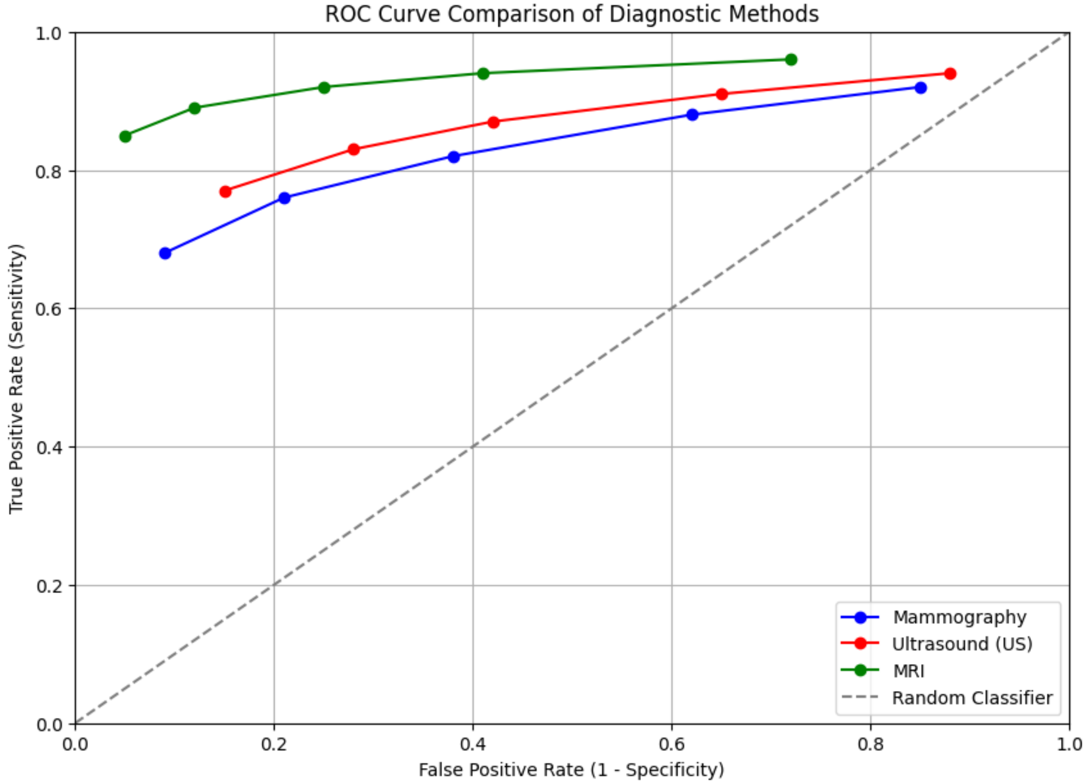

Figure 3. ROC Curve for Diagnostic Accuracy of Mammography, MRI, and US

Discussion

The current study aimed to evaluate the diagnostic accuracy of mammography, US, and MRI in detecting breast cancer at King Saud Medical City. The findings reveal significant insights into the comparative effectiveness of these imaging modalities based on sensitivity, specificity, and predictive values.

Summary of Findings

Our analysis demonstrated that MRI exhibited the highest overall accuracy at 91.7%, followed by mammography at 87.5% and US at 88.1%. These results align with existing literature that underscores the superior sensitivity of MRI in breast cancer detection, particularly in dense breast tissues where mammography may underperform (Houser et al., 2021).

Sensitivity and Specificity

MRI's sensitivity of 98.6% suggests its capability to identify true positive cases, thereby minimizing false negatives accurately. In contrast, while mammography showed a sensitivity of 95.8%, its specificity was notably lower at 42.3%. The US demonstrated excellent sensitivity (97.2%) but had low specificity (38.5%). This finding suggests that while the US is valuable in identifying lesions, it may lead to a higher rate of false positives, necessitating further investigation via biopsy or other imaging modalities (Alqahtani et al., 2020).

Clinical Implications

The results of this study have significant implications for clinical practice. Given the high accuracy of MRI, it could be recommended as a supplementary imaging technique for high-risk patients or those with inconclusive mammography results. Conversely, mammography remains a cornerstone for routine screening due to its high specificity and established guidelines for breast cancer detection (Centers for Disease Control and Prevention, 2024).

The observed limitations of the US highlight the need for careful interpretation of results, particularly when used as a standalone diagnostic tool. Clinicians should consider integrating the US with mammography and MRI to enhance diagnostic accuracy for patients with complex cases or dense breast tissue.

Limitations of the Study

It is essential to acknowledge the limitations of this study. Its retrospective nature may introduce biases related to case selection and data completeness. Additionally, the focus on a specific patient population at King Saud Medical City may limit the generalizability of the findings. Notably, this research primarily included female patients, and there was a lack of data for male participants diagnosed with breast cancer. This absence of male data restricts the understanding of the diagnostic accuracy of imaging modalities across genders. Future research should aim for larger, more diverse samples that include male participants and utilize prospective study designs to validate these results. Addressing this gap is crucial for optimizing breast cancer diagnostic practices and ensuring comprehensive care for all patients.

Recommendations for Future Research

Future studies should explore the cost-effectiveness of implementing MRI as a first-line imaging modality in various populations. Additionally, larger, multicentric studies are recommended to validate these findings and assess the performance of these imaging techniques across different demographics and clinical settings.

Conclusion

This study comprehensively evaluates the diagnostic performance of mammography, US, and MRI for breast cancer detection at King Saud Medical City. Our findings underscore the critical role of multimodal imaging strategies in enhancing diagnostic accuracy and optimizing patient outcomes.

The analysis demonstrates that MRI exhibits the highest diagnostic accuracy at 91.7%, followed by US at 88.1% and mammography at 87.5%. These results highlight the unique strengths and limitations of each imaging modality. MRI's exceptional sensitivity (98.6%) is particularly advantageous for high-risk individuals and those with dense breast tissue, where mammography may have reduced efficacy. These findings suggest that integrating MRI into standard diagnostic protocols could significantly enhance patient management, especially in complex cases.

Furthermore, the study emphasizes the paramount importance of continuous professional development and training for radiologists and technicians. Enhancing interpretive skills is crucial for optimizing diagnostic accuracy and minimizing unnecessary biopsies and follow-up procedures resulting from misdiagnoses. Implementing regular training programs ensures that healthcare professionals remain abreast of advancements in imaging technologies and best practices.

The research also identifies significant barriers to effective breast cancer screening in Saudi

Arabia, including cultural beliefs and limited healthcare accessibility. Addressing these challenges through targeted public health initiatives and comprehensive educational outreach is crucial for increasing early detection rates and improving treatment outcomes. Fostering public awareness of breast cancer risks and the value of regular screenings is essential for promoting proactive health management.

In conclusion, this research advocates for a personalized approach to breast cancer screening that utilizes a combination of imaging modalities tailored to individual patient needs. Future research should include larger and more diverse populations to further validate these findings and explore the integration of advanced technologies, such as artificial intelligence (AI). We believe that implementing AI tools could streamline the diagnostic process and alleviate the burden on radiologists.

Continued research and innovation are essential for refining breast cancer detection methods and enhancing the quality of patient care. By addressing the identified challenges and embracing new technologies, healthcare providers can significantly improve diagnostic outcomes, leading to timely interventions and better overall patient experiences. Improving breast cancer detection strategies is crucial for reducing mortality rates and enhancing the quality of life for individuals affected by this prevalent disease.

Recommendations

Based on the findings of this study evaluating the diagnostic accuracy of mammography, US, and MRI in detecting breast cancer at King Saud Medical City, the following recommendations are proposed:

Implement a Multimodal Imaging Approach: A multi-modal imaging strategy, utilizing a combination of mammography, US, and MRI as clinically indicated, is recommended to enhance diagnostic accuracy. Given MRI's demonstrated high accuracy (91.7% in this study), its integration with mammography, particularly for high-risk individuals or when mammography results are inconclusive, should be considered.

Invest in Continuous Professional Development: Ongoing training programs for radiologists and technologists are crucial to ensure proficiency in the latest imaging techniques and the interpretation of imaging findings. These programs should emphasize the importance of accurate image interpretation and the minimization of diagnostic errors.

Enhance Breast Cancer Screening Programs: Existing breast cancer screening programs should be strengthened, encouraging regular mammograms for women aged 30-74 years, as per current health recommendations. Public awareness campaigns should be implemented to educate the public about the importance of early detection and the benefits of utilizing appropriate imaging modalities.

Conduct Further Research: Future research should encompass larger and more diverse populations, including men, to further validate these findings. Additionally, studies investigating the performance of these imaging modalities in various clinical settings are warranted to broaden our understanding of their effectiveness.

Personalize Screening Strategies: Individualized screening plans should be developed based on patient-specific risk factors, such as family history and age. This personalized approach will ensure that the most appropriate imaging modalities are utilized for each patient.

Explore the Potential of AI: Integrating artificial intelligence (AI) and machine learning algorithms into breast imaging analysis should be explored. These technologies have the potential to significantly improve the accuracy and efficiency of image interpretation by assisting radiologists in identifying potential abnormalities.

By implementing these recommendations, healthcare providers at King Saud Medical City can significantly improve breast cancer detection rates, enhance diagnostic accuracy, and improve patient outcomes.

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