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BREAST CANCER DIAGNOSIS: A COMPARATIVE STUDY OF METHODS BASED ON SENSITIVITY AND SPECIFICITY

Muthulingam Sharavanan Gayathri Srikanth*, Kalash Dwivedi, Vinayak Koli , Jainil Sejpal Karthigeyan S, Karthik Shrishail Vastrad, Rohan Rajendra Patil, Surajit Bose

Students of Tashkent medical Academy, Tashkent Uzbekistan .

Abstract: This study compares different methods for diagnosing breast cancer, focusing on their sensitivity, specificity, and clinical usefulness. Using the PICO framework, we reviewed key studies published from 2002 to 2024, sourced from databases like PubMed, Scopus, and Google Scholar. In total, we analysed 8 studies, covering a range of diagnostic techniques. These methods include traditional approaches like Core Needle Biopsy (CNB) and Fine Needle Aspiration (FNA), as well as more advanced methods such as Abbreviated MRI (ABB-MRI), image segmentation algorithms, Raman and infrared spectroscopy, blood-based proteomics, and cytometric testing. The findings showed that CNB had the highest diagnostic performance overall. However, ABB-MRI and some molecular techniques offered strong non-invasive alternatives. Computational tools, while promising, still need more validation for widespread use. In conclusion, no single diagnostic method stood out as the best for all cases. Instead, a combination of different approaches, tailored to each patient's specific situation, seems to be the most accurate and efficient strategy for detecting breast cancer.

Keywords: Breast cancer, diagnosis, sensitivity, specificity, core needle biopsy, MRI, spectroscopy, proteomics, image segmentation, SCM test.

INTORDUCTION

In breast cancer diagnosis, the clinical relevance of sensitivity and specificity cannot be overstated, as these metrics directly impact patient outcomes by guiding therapeutic decisions and minimizing diagnostic errors. Sensitivity ensures that malignant cases are correctly identified, crucial for initiating timely treatment and preventing disease progression. Specificity, on the other hand, reduces false positives, sparing patients from unnecessary anxiety, biopsies, and interventions. The ideal diagnostic method balances both, adapting to clinical needs whether in screening asymptomatic populations or confirming malignancy in symptomatic patients. With evolving technologies—from imaging modalities like MRI to molecular and computational diagnostics—emphasis on sensitivity and specificity helps clinicians choose the most effective approach for each scenario. As breast cancer presentations and patient risk profiles vary, the nuanced application of these performance metrics ensures more accurate, patient-centred care and supports the broader goals of early detection and personalized oncology.

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Methodology

This study employs the PICO (Population, Intervention, Comparison, Outcome) framework to structure its clinical inquiry into the diagnostic accuracy of various breast cancer detection methods. The **Population (P)** focuses on women undergoing diagnostic evaluation for

Study	Method	Key Finding	Advantages	Disadvantages
Ibrahim et al. (2024)	CNB vs FNA	CNB more sensitive; both highly specific	Highly accurate; standard for histological confirmation	More invasive; requires trained personnel
He et al. (2023)	ABB-MRI	High sensitivity/specificity; good for high-risk women	Non-invasive; useful in dense breast tissue	Limited availability; requires MRI setup
KuÅŸÃ§u & Erol (2022)	K-Mean Clustering	Effective in image-based diagnostics	Automates tumor detection; useful in digital diagnostics	Dependent on quality of image input and algorithm
KuÅŸÃ§u & Erol (2022)	Otsu Thresholding	Comparable to K-Mean; slightly less accurate	Simple image processing technique; effective in segmentation	Lower accuracy than K-Mean; sensitive to pixel noise
MartÃnez Romo et al. (2015)	Raman Spectroscopy	Perfect sensitivity and specificity in trial	Real-time, intraoperative use; exceptional accuracy	Requires spectral tools and expertise
Backhaus et al. (2010)	IR Spectroscopy	Highly accurate in serum-based detection	Non-invasive serum analysis; excellent diagnostic potential	May face overlap in spectral patterns with other diseases
Khoroushi et al. (2024)	Ultrasound-Guided FNA	Accurate for nodal metastasis detection	Reliable pre-surgical tool for nodal assessment	May miss micrometastases; operator-dependent
Drukier et al. (2006)	Multiphoton Proteomics	Effective blood-based screening tool	Early detection from blood; high accuracy in screening	High cost and complex data interpretation
Klein et al. (2002)	SCM Test	Useful in early malignancy detection	Useful for distinguishing benign vs malignant in early stage	Not widely used; needs more clinical validation

suspected breast cancer. The **Intervention (I)** includes a range of diagnostic methods such as Core Needle Biopsy (CNB), Fine Needle Aspiration (FNA), Abbreviated MRI (ABB-MRI), image segmentation techniques, spectral diagnostics, and blood-based proteomics. The **Comparison (C)** contrasts the sensitivity, specificity, and diagnostic accuracy of these methods. The **Outcome (O)** evaluates each method's effectiveness in terms of these diagnostic parameters.

A systematic literature review was conducted using major academic databases including **PubMed**, **Google Scholar**, **Scopus**, **Web of Science**, and the **Cochrane Library**. Search terms included combinations of "breast cancer", "diagnosis", "sensitivity", "specificity", "accuracy", "MRI", "biopsy", "spectroscopy", and "machine learning". Boolean operators (AND, OR) and MeSH terms were used to optimize search results. After removing duplicates and screening for relevance, 15 initial articles were shortlisted. From these, **10 studies** were selected based on inclusion criteria: English-language full-text availability, quantitative diagnostic data, publication between 2002 and 2024, and clinical relevance.

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The 10 studies chosen represent a diverse spectrum of diagnostic methodologies, including traditional pathological assessments (CNB and FNA), imaging-based techniques (ABB-MRI), computational image analysis (K-means and Otsu methods), molecular diagnostics (Raman and IR spectroscopy), node-focused cytology (ultrasound-guided FNA), biomarker-based assays (multiphoton proteomics), and antigen-responsive cytometry (SCM test). These studies provide robust comparative insights into the diagnostic landscape, facilitating evidence-based evaluation of breast cancer detection strategies across clinical and technological dimensions.

Results

Table.1. Comparative Performance of Breast Cancer Diagnostic Methods with Sensitivity, Specificity, Key Findings, and Practical Considerations

Study	Method	Sample Size	Sensitivity	Specificity	Accuracy
Ibrahim et al. (2024)	CNB vs FNA	1177 patients	88.1% / 68.6%	97.2% / 96.1%	-
He et al. (2023)	ABB-MRI	18 studies (meta-analysis)	87%	90%	-
KuÅŸÃ§u & Erol (2022)	K-Mean Clustering	9 images	89%	87%	87%
KuÅŸÃ§u & Erol (2022)	Otsu Thresholding	9 images	84%	87%	84%
MartÃnez Romo et al. (2015)	Raman Spectroscopy	Unknown	100%	100%	100%
Backhaus et al. (2010)	IR Spectroscopy	3119 samples	98%	100%	91%-100%
Khoroushi et al. (2024)	Ultrasound-Guided FNA	102 patients	93.60%	96.30%	95.10%
Drukier et al. (2006)	Multiphoton Proteomics	250 samples + 95 controls	95%	95%	-
Klein et al. (2002)	SCM Test	137 patients	81%	85%	-

The comparative analysis of the 8 selected studies revealed significant variability in diagnostic performance among the evaluated methods, particularly in terms of sensitivity, specificity, and overall clinical utility. Core Needle Biopsy (CNB) consistently demonstrated superior diagnostic performance with a sensitivity of 88.1% and specificity of 97.2%, making it a preferred standard for tissue-based confirmation. In contrast, Fine Needle Aspiration (FNA), while still widely used due to its simplicity and accessibility, showed lower sensitivity at 68.6% but maintained a high specificity of 96.1%. Abbreviated MRI (ABB-MRI) emerged as an effective imaging technique, with pooled sensitivity and specificity of 87% and 90%, respectively, proving valuable especially in high-risk and dense breast populations. Computational image analysis methods such as K-Mean Clustering and Otsu Thresholding showed promising accuracy rates ranging from 84% to 89%, supporting their role as supplementary tools in automated diagnostics. Molecular-based diagnostics also yielded highly favorable outcomes: Raman spectroscopy achieved 100% sensitivity and specificity in select trials, while infrared spectroscopy reported up to 98% sensitivity and 100% specificity in serum-based cancer detection. Ultrasound-guided FNA of axillary lymph nodes showed strong diagnostic accuracy with 93.6% sensitivity and 96.3% specificity, aiding in preoperative staging. Proteomic approaches using multiphoton detection in blood samples reported approximately 95% for both sensitivity and specificity, highlighting the potential for non-invasive early detection. Lastly, cytometric methods like the SCM test using tumor antigens achieved 81% sensitivity and 85% specificity, indicating potential utility in early malignancy screening. Overall, these findings emphasize that while traditional methods remain essential, integrating newer imaging, spectral, and blood-based technologies can enhance diagnostic precision and support personalized breast cancer management.

Discussion

This review highlights the variability and complementary strengths of multiple diagnostic methods used in breast cancer detection. Core Needle Biopsy (CNB) emerges as a gold standard due to its high sensitivity and specificity, making it ideal for confirming malignancy. Fine Needle Aspiration (FNA), while less sensitive, remains valuable in resource-limited settings or for quick preliminary assessments. Abbreviated MRI (ABB-MRI) provides a non-invasive, high-performance imaging option, particularly beneficial for women with dense breast tissue or elevated genetic risk profiles. Emerging computational tools, such as K-Mean clustering and Otsu thresholding, offer promising automation in imaging interpretation, though further validation is required for clinical integration. Molecular diagnostics—like Raman and infrared spectroscopy—deliver exceptional accuracy and are gaining traction as intraoperative tools or supplementary screening measures. Blood-based methods, including multiphoton proteomics and antigen-driven SCM testing, offer innovative, minimally invasive pathways for early detection and monitoring. Collectively, these studies underscore the importance of context-specific application, where a method's sensitivity, specificity, and feasibility guide its clinical utility. The integration of these diagnostic tools into a multimodal strategy may enhance early detection, reduce diagnostic errors, and promote individualized patient care.

Conclusion

Breast cancer diagnosis is evolving rapidly, driven by technological innovation and the demand for higher diagnostic accuracy. No single method is universally optimal; each has its advantages and limitations. Core Needle Biopsy remains the most reliable for tissue confirmation, while imaging modalities like ABB-MRI provide excellent non-invasive alternatives. Spectral and molecular methods push the boundaries of diagnostic precision, and computational tools open avenues for efficient and reproducible analysis. As sensitivity and specificity remain central to diagnostic performance, their careful evaluation ensures that the chosen method aligns with patient needs and clinical objectives. A tailored, multimodal diagnostic approach that leverages the strengths of each method offers the best pathway to early detection, reduced morbidity, and improved outcomes in breast cancer care.

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