

# Artificial Intelligence and Breast Surgery: Challenges, Opportunities and Future Directions. A Literature Review

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**Abstract:** The intersection of artificial intelligence (AI) and breast surgery presents a transformative opportunity within the medical landscape, promising advancements that enhance precision and patient care. As the technology matures, AI is poised to revolutionize various aspects of surgical practice—from preoperative planning to postoperative recovery. The integration of machine learning algorithms allows for sophisticated analysis of medical imaging, enabling personalized surgical strategies tailored to individual patients, ultimately improving excision accuracy and preserving healthy tissue. Additionally, AI's role extends into predicting postoperative complications, thereby facilitating timely interventions that enhance patient outcomes. The employment of robotic systems in breast surgery showcases AI's potential to refine surgical procedures through real-time feedback and enhanced visualization, leading to improved recovery experiences for patients. However, this integration is not without challenges, including ethical considerations about patient data privacy and questions surrounding equitable access to these advanced technologies. As the field progresses, a comprehensive exploration of AI applications in breast surgery will illuminate both the challenges and opportunities that lie ahead, guiding future research and enhancing clinical practices in this critical area of healthcare.

**Keywords:** artificial intelligence, breast surgery, machine learning, medical imaging, patient outcomes.

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## 1. INTRODUCTION

The emergence of artificial intelligence (AI) in medicine marks a transformative period characterized by enhanced capabilities in diagnostics, surgical precision, and patient care. AI technologies, particularly machine learning algorithms, have demonstrated significant promise in analyzing complex medical data and improving treatment outcomes. For instance, AI facilitates precise surgical planning in breast surgery by evaluating imaging data to tailor approaches to individual patients, resulting in better tumor excision and tissue preservation (1). Additionally, AI's application extends beyond the operating room; it holds potential in predicting postoperative complications and assessing patient-reported outcomes, thereby guiding clinical decision-making and enhancing patient experiences (2). Nevertheless, the integration of AI in medicine is not without challenges, including data reliability and ethical implications. As the field continues to evolve, ongoing research will be crucial to harness AI's full potential in breast surgery and refine its contributions to patient management (3,4).

Breast surgery practices encompass a range of procedures aimed at treating breast diseases, notably breast cancer, while simultaneously addressing aesthetic concerns. The landscape of these practices has evolved dramatically with the incorporation of advanced technologies and techniques, including robotic surgery and artificial intelligence (AI). Robotic breast surgery enhances precision and safety, allowing for minimally invasive approaches that often lead to quicker recovery times and improved patient satisfaction. Additionally, AI applications are becoming increasingly prevalent; they assist in preoperative planning, risk prediction, and intraoperative guidance, ultimately optimizing surgical outcomes (5). The integration of machine learning in surgical processes enables the customization of treatment plans based on individual patient data, significantly enhancing the quality of care (1). Furthermore, ongoing research highlights the role of AI in postoperative management, offering tailored follow-up schedules and improving resource allocation (6). Collectively, these advancements signify a shift toward more patient-centered practices in breast surgery (2).

The integration of artificial intelligence (AI) in breast surgery represents a transformative shift that enhances both surgical precision and patient outcomes. By implementing machine learning algorithms, surgeons can significantly improve preoperative planning, allowing for detailed, patient-specific strategies that optimize tumor excision and minimize healthy tissue loss. AI also plays a crucial role during surgery, ensuring intraoperative assistance such as real-time anatomical feedback and surgical visualizations that enhance accuracy (1). Furthermore, AI's predictive capabilities extend into postoperative care, where it assists in anticipating patient needs and optimizing follow-up schedules (1). The ethical implications of these advancements cannot be overlooked, as equitable access to AI technologies must be ensured alongside their development (6). Collectively, the integration of AI in breast surgery not only improves the efficacy of surgical procedures but also elevates the overall quality of care provided to patients (2).

The objectives and scope of the literature review on "Artificial Intelligence and Breast Surgery" are to systematically explore the transformative potential of AI technologies within this critical area of medicine. By assessing contemporary research and applications, this review aims to identify specific benefits, such as enhanced surgical precision, reduced planning time, and improved postoperative outcomes. For instance, existing studies indicate that AI can decrease surgical planning time by up to 35% and enhance symmetry assessment accuracy beyond 90% (5). Furthermore, the integration of robotic systems and machine learning offers real-time assistance during surgery, thereby augmenting clinical decisions and patient management (7). This literature review also critically examines ethical challenges and the impact of algorithmic bias, ensuring a comprehensive understanding of AI's implications and paving the way for its responsible adoption in breast surgery (1). Ultimately, the review underscores the necessity for ongoing research to realize AI's full potential in enhancing patient care (2).

### **Challenges of Implementing AI in Breast Surgery**

The integration of artificial intelligence (AI) in breast surgery presents significant challenges that must be addressed to harness its full potential. One major obstacle is the necessity for comprehensive data to train machine learning algorithms effectively; without a robust dataset, predictive models may yield unreliable results, undermining clinical decision-making (8). Additionally, ethical concerns surrounding patient privacy and the ownership of medical data pose substantial barriers to implementation, as healthcare providers must navigate complex regulations while ensuring compliance with patient confidentiality (5). Furthermore, there is concern about the clinical acceptance of AI-driven tools among surgeons, many of whom may be hesitant to rely on algorithms for critical surgical decisions (1). This skepticism can hinder the adoption of innovations that could enhance precision and outcomes in breast surgery. Lastly, the financial implications of incorporating AI technology into clinical practice are noteworthy; the costs associated with developing, implementing, and maintaining these systems may deter hospitals and clinics from embracing such advancements (2). In sum, while the challenges are formidable, addressing these barriers is essential for the successful implementation of AI in breast surgery, thereby enhancing patient care and surgical efficacy.

As artificial intelligence (AI) becomes increasingly integrated into breast surgery, the implications for data privacy and ethical considerations warrant critical evaluation. The use of AI technologies raises significant concerns regarding patient autonomy, particularly in the context of informed consent, as medical practitioners may inadvertently depend on AI systems for decision-making (9). Moreover, the risk of algorithmic bias necessitates rigorous scrutiny to ensure equitable treatment outcomes and prevent disparities in patient care, as it could perpetuate existing inequities (10). Data protection is paramount, particularly considering the sensitive nature of health information; breaches could result in severe ramifications for patient

trust and safety (11). The lack of established regulations surrounding AI utilization in healthcare exacerbates these ethical dilemmas, highlighting the urgent need for comprehensive frameworks governing algorithmic transparency and cybersecurity to safeguard patient welfare (12). Thus, addressing these ethical challenges is imperative for fostering a responsible integration of AI into breast surgery practices.

The accuracy and reliability of artificial intelligence (AI) algorithms in breast surgery are paramount to ensuring patient safety and optimizing surgical outcomes. Various studies have demonstrated that AI enhances surgical precision, as seen in robotic systems that can perform minimally invasive procedures with remarkable accuracy, potentially reducing surgical time by up to 35% and improving breast symmetry assessments by over 90%. Furthermore, AI's ability to predict postoperative complications and provide real-time analytical feedback strengthens clinical decision-making during operations (2). However, these advancements are not without challenges, as issues such as algorithmic bias and data privacy concerns may undermine the reliability of AI applications in surgical contexts (1). The integration of AI into breast cancer care also necessitates rigorous clinical validation to ensure predictive models are robust and effective (3). Therefore, while AI presents significant opportunities in breast surgery, meticulous attention to the accuracy and reliability of its algorithms remains critical for its effective implementation (1).

The integration of artificial intelligence (AI) into existing clinical workflows represents both a challenge and an opportunity for breast surgery. As healthcare continues to evolve, the adoption of AI can enhance surgical planning, postoperative care, and overall patient management, making it an indispensable component of modern clinical practice. For instance, AI algorithms have demonstrated their effectiveness in predicting postoperative complications, thereby improving risk stratification and decision-making processes in breast reconstruction (2). By streamlining the data analysis of complex medical information, AI empowers clinicians to optimize surgical interventions and personalize patient care (8). However, the assimilation of these technologies requires overcoming significant barriers, including the need for training and familiarization among medical personnel and addressing diverse healthcare environments (13). Moreover, as AI tools continue to advance, they hold the potential to reduce healthcare disparities, particularly in underserved regions (14). Thus, strategically integrating AI into clinical workflows is essential for enhancing the efficacy and accessibility of breast surgery.

The integration of artificial intelligence (AI) into breast surgery presents significant regulatory and legal barriers that must be addressed for successful implementation. As AI technologies evolve, existing regulations often struggle to keep pace, creating a landscape where compliance with outdated standards can hinder innovation. For instance, the rapid development of AI applications necessitates updates to the Health Insurance Portability and Accountability Act (HIPAA) to address data privacy concerns in surgical settings, ensuring patient confidentiality while facilitating effective AI utilization (15). Moreover, ethical implications arise regarding algorithmic bias and transparency, prompting calls for an independent regulatory body to oversee AI integration in surgical practice (11). Furthermore, the legislative landscape is evolving, with multiple states proposing laws to either promote or restrict AI applications in healthcare (6). Therefore, robust frameworks that prioritize patient welfare while fostering technological advancement are essential to navigate these complex regulatory landscapes (14). Addressing these barriers will be crucial in validating AI's role in enhancing breast surgery outcomes.

### **Opportunities Presented by AI in Breast Surgery**

The integration of artificial intelligence (AI) into breast surgery presents a multitude of opportunities that enhance surgical precision, improve patient outcomes, and streamline healthcare processes. AI technologies leverage machine learning and computer vision to assist surgeons during preoperative planning, enabling tailored surgical strategies based on individual patient anatomy and tumor characteristics, thus enhancing the accuracy of tumor excision and preserving healthy tissue (1). Furthermore, machine learning algorithms can predict postoperative complications, promoting proactive patient management and optimizing resource allocation (1). The use of AI in aesthetic evaluation has also gained prominence, as neural networks provide objective assessments of surgical results, thereby facilitating better communication with patients (2). Additionally, AI enhances educational resources for surgeons, offering personalized feedback that is essential for skill development (5). The deployment of robotic systems equipped with AI further elevates the quality of care by providing real-time feedback and improving surgical techniques. As these technologies mature, they promise to redefine breast surgery, making it more efficient and patient-centered, while also stimulating ongoing research and innovation in the field. However, it is crucial to address the ethical implications and access disparities that accompany these advancements to ensure equitable benefits for all patients.

The integration of artificial intelligence (AI) into breast surgery represents a transformative opportunity to enhance diagnostic precision and facilitate early detection of breast cancer. One of the critical advancements lies in AI's application to mammography, where algorithms can analyze imaging data to improve diagnostic accuracy, addressing the prevalent issues of false positives and missed diagnoses. Furthermore, machine learning techniques have shown promise in breast ultrasound, automating lesion detection and providing radiologists with accurate classifications of lesions, thereby improving patient outcomes (1). The development of these sophisticated AI systems not only helps streamline the workflow but also allows medical professionals to dedicate more time to direct patient care (16). However, the path toward widespread adoption is fraught with challenges, including data privacy concerns, interpretability of AI decisions, and potential biases in algorithm training. As researchers continue to refine these technologies, collaborative approaches that involve clinicians, AI developers, and regulatory bodies are crucial for overcoming obstacles and ensuring ethical implementation to maximize the benefits of AI in breast surgery (1).

The integration of artificial intelligence (AI) into personalized surgical planning marks a significant advancement in breast surgery, enabling tailored approaches that enhance patient outcomes. Surgeons can utilize machine learning algorithms and advanced imaging techniques to analyze a patient's unique anatomy and tumor characteristics, facilitating the creation of detailed surgical plans that prioritize precision and minimize tissue damage (1). Furthermore, these algorithms can predict postoperative complications by examining a wide array of clinical data, allowing for proactive measures to enhance recovery (2). The incorporation of AI not only streamlines intraoperative decision-making but also elevates the quality of preoperative evaluations, enhancing patient education and involvement in the decision-making process (8). As robotic systems and AI technologies evolve, they are set to redefine the landscape of surgical strategies, offering unprecedented opportunities for individualized care (6). Embracing these innovations in personalized surgical planning promises to improve surgical efficacy, thereby enhancing the overall experience and outcomes for breast surgery patients.

The automation of routine tasks in breast surgery through artificial intelligence (AI) enhances workflow efficiency, allowing surgeons to focus on more intricate aspects of patient care. AI technologies actively streamline processes such as preoperative planning and postoperative monitoring by analyzing vast datasets to predict surgical outcomes and complications. For example, AI algorithms can assess medical imaging data for precise tumor localization, thereby informing tailored surgical strategies that improve patient outcomes (1). Moreover, the integration of machine learning and natural language processing in everyday surgical practice allows for personalized patient interactions, ensuring thorough education and informed consent while optimizing time management during clinic hours (2). Additionally, AI's capability to predict discharge times and customize follow-up schedules reduces hospital congestion and enhances resource allocation (5). Despite promising advancements, the challenges of privacy and the need for further exploration of AI's limitations remain critical as surgeons work to seamlessly integrate these technologies into their workflows (8).

The integration of artificial intelligence (AI) into breast surgery has brought forth significant improvements in patient outcomes and postoperative monitoring. By employing machine learning algorithms that analyze a multitude of patient-specific factors, AI enhances the precision of surgical planning and intraoperative procedures, leading to more tailored interventions that minimize complications. For instance, AI systems can proactively predict postoperative complications, allowing clinicians to implement preventative measures promptly, thereby optimizing recovery for patients (3). Furthermore, AI's capabilities extend to monitoring patient-reported outcomes, facilitating better communication and alignment of treatment goals between patients and healthcare providers (14). The scalability of AI applications is particularly crucial in underserved regions, where it can address disparities in breast cancer care by making advanced monitoring tools more accessible (1). As AI continues to evolve, its role in shaping postoperative strategies is essential for improving quality of care and ensuring better long-term results for breast cancer patients (2).

### **Future Directions and Innovations in AI for Breast Surgery**

As breast surgery continues to evolve, the integration of artificial intelligence (AI) presents innovative pathways that promise to enhance surgical accuracy and patient care. Future directions for AI in breast surgery encompass advancements in machine learning algorithms that can analyze vast medical datasets, thus facilitating better preoperative planning and personalized surgical strategies. For instance, neural networks could provide precise predictions regarding complications and patient-reported outcomes, enabling surgeons to tailor interventions to individual patient circumstances more effectively (2). Furthermore, robotic systems equipped with AI capabilities stand to drastically improve intraoperative techniques,

ensuring greater precision in tumor excisions while minimizing the risk of collateral damage to surrounding tissues (1). Additionally, the exploration of AI's role in postoperative care is critical, as it can streamline discharge processes and optimize follow-up schedules, thereby enhancing resource management within healthcare systems (5). Ethical considerations surrounding AI's implementation, including informed consent and equitable access to technological advancements, must also be addressed as the field progresses (6). Therefore, the potential of AI not only to reshape the landscape of breast surgery but also to foster patient-centered care is immense. Ongoing research and development will be essential, enabling clinicians to fully leverage these tools to improve surgical outcomes and overall patient health.

The continuous evolution of machine learning and deep learning techniques has significantly impacted various domains of healthcare, particularly in breast surgery. Innovations in AI applications have led to enhanced surgical precision, with algorithms that analyze complex medical imaging data to inform preoperative planning and intraoperative decision-making. These advancements are underscored by a review highlighting the potential of AI to optimize surgical care, improve patient outcomes, and facilitate surgical education (4). Moreover, deep learning methodologies enable the development of predictive models that assist in clinical decision-making, ultimately leading to better patient management strategies (17). However, the integration of these technologies is not without challenges, as issues related to data quality, algorithmic transparency, and ethical considerations persist (18). As robotic surgical systems increasingly incorporate AI-assisted features, the future of breast surgery appears promising, with the expectation that continued advancements will substantially improve the quality of care delivered to patients (1).

The development of AI-driven surgical robotics marks a pivotal shift in the landscape of breast surgery, merging cutting-edge technology with clinical precision. Recent literature underscores the transformative potential of integrating artificial intelligence into robotic systems, enhancing the accuracy of procedures while minimizing invasiveness. As noted, AI enables sophisticated data analysis from preoperative imaging, allowing for tailored surgical plans that address each patient's specific needs (1). Furthermore, the review highlights the ethical considerations surrounding these technological advancements, emphasizing the need for equitable access to robotic-assisted surgeries, which could redefine standards of care across diverse patient demographics (6). Significantly, the application of machine learning algorithms has facilitated improved real-time feedback during surgeries, leading to higher success rates and reduced complication risks (19). As the field continues to evolve, ongoing research will be essential in optimizing these autonomous systems, ensuring AI not only enhances surgical capabilities but also establishes a new paradigm in patient-centered care (20).

The collaboration between multidisciplinary teams and AI experts is pivotal in enhancing outcomes in breast surgery, as integrating advanced technologies necessitates a comprehensive understanding of clinical and operational nuances. The synergy of surgical specialists, data scientists, and AI developers fosters innovative approaches, enabling the precise application of AI in areas such as preoperative planning and postoperative care. As AI tools become more sophisticated, they can predict complications and optimize treatment paths, showcasing the transformative potential of these collaborations (2). Furthermore, AI's capacity to analyze 'big data' enhances diagnostic accuracy and facilitates tailored patient care, addressing disparities in global healthcare access (14). However, as AI integrates deeper into surgical practices, establishing a balance between machine capabilities and human expertise is crucial for effective implementation (21). Such multidisciplinary partnerships are essential for navigating the complexities and harnessing the full benefits of AI in breast surgery, driving future advancements in the field (22).

The incorporation of real-time artificial intelligence (AI) assistance during surgical procedures represents a transformative advancement in breast surgery, enhancing both precision and outcomes. AI systems, equipped with machine learning algorithms and advanced imaging technologies, can assist surgeons in various phases of the operation, from preoperative planning to intraoperative execution. For instance, predictive algorithms can analyze patient-specific data to optimize surgical approaches and anticipate potential complications, thereby improving decision-making and reducing risk (6). Additionally, the use of AI-driven robotic systems offers surgeons unprecedented control and accuracy in delicate procedures, such as tumor excision and reconstructive tasks, further maximizing the preservation of healthy tissue (1). Moreover, AI can provide continuous feedback during operations, enabling real-time adjustments and fostering enhanced surgical training through personalized performance metrics (5). Despite these innovations, ongoing concerns regarding ethical implications, data privacy, and equitable access must be addressed to fully realize the potential of AI in breast surgery (2). As research and development continue, the future of AI assistance in surgical settings looks promising, setting the stage for improved patient care.

## 2. CONCLUSION

In conclusion, the integration of artificial intelligence (AI) into breast surgery presents a transformative opportunity that transcends traditional practices, while also underscoring significant challenges. As highlighted in the literature, AI's capacity for enhancing surgical precision, such as through machine learning algorithms that predict postoperative complications, is reshaping breast reconstruction techniques and clinical outcomes (2). Furthermore, the advent of robotic systems in surgical settings demonstrates the potential for AI to streamline procedures and improve patient care, making surgeries less invasive and more effective (1). Nonetheless, the journey toward widespread AI adoption is fraught with hurdles, including ethical considerations and the need for robust training among practitioners (3). Moreover, as the landscape of breast cancer care evolves with AI innovations, it is crucial to address the metrics for evaluating AI performance to ensure trust and reliability (5). Moving forward, a concerted effort must be made to navigate these challenges while harnessing the full range of opportunities AI presents, ultimately aiming to enhance the quality of care provided to patients undergoing breast surgery.

The extensive literature on artificial intelligence (AI) in breast surgery highlights significant advancements and critical applications that enhance surgical practices. AI's integration into breast reconstruction has revolutionized clinical decision-making, with machine learning algorithms adept at predicting postoperative outcomes and complications, thus improving patient care and surgical planning (2). Furthermore, innovative technologies such as robotic surgery benefit from AI by utilizing enhanced imaging analyses for tailored surgical strategies and real-time feedback, which contributes to more precise surgical interventions (1). The utilization of AI spans various stages of surgical procedures, from enhancing preoperative assessments to optimizing postoperative management through predictive analytics (5). Additionally, the growing body of research underscores the importance of addressing challenges related to privacy and operational efficacy, ensuring that AI's implementation in clinical practice is both ethical and effective (8). Overall, the insights gathered from the literature indicate a promising future for AI in breast surgery, warranting further exploration and development.

The integration of artificial intelligence (AI) into breast surgery exemplifies a striking balance between the inherent challenges and the promising opportunities that accompany technological advancement. While AI holds the potential to streamline surgical processes, enhance patient outcomes, and refine decision-making strategies, it also presents significant hurdles that must be addressed. Concerns regarding data privacy, algorithmic biases, and the need for rigorous validation pose substantial barriers to seamless implementation in clinical settings. For instance, AI technologies such as machine learning are employed to predict surgical complications and personalize patient care (23), while robotic systems enhance precision in surgical procedures (1). However, these innovations necessitate enhancements in data quality and ethical frameworks, which must be prioritized to mitigate risks (5). Furthermore, the successful integration of AI requires training healthcare professionals to effectively utilize these tools without compromising clinical judgment. Therefore, a concerted effort is essential to foster collaboration between technologists and the medical community, ensuring that the opportunities presented by AI lead to transformative changes in breast surgery while responsibly addressing the associated challenges (2).

The implications of artificial intelligence (AI) for clinical practice and patient care in breast surgery are profound and far-reaching. As AI technologies become increasingly integrated into surgical workflows, they offer significant enhancements in precision and efficiency, ultimately leading to improved patient outcomes. For instance, predictive models developed through machine learning can forecast postoperative complications, enabling timely interventions and thereby enhancing patient safety (7). Furthermore, AI facilitates personalized approaches to surgical planning by analyzing individual patient data, which can be crucial for tailoring treatments to specific tumor characteristics (1). In addition, AI-powered tools are enhancing postoperative monitoring and communication, resulting in more comprehensive patient education and support (2,3). These advancements not only improve procedural accuracy but also foster a more patient-centered care model, ensuring that individuals are better informed and engaged throughout their treatment journey. However, it remains essential for healthcare professionals to navigate the associated ethical challenges and maintain transparency in the implementation of these technologies, ensuring optimal care remains at the forefront.

The future of artificial intelligence (AI) in breast surgery necessitates targeted research and development to fully harness its transformative potential. It is imperative for researchers to focus on integrating machine learning algorithms into preoperative planning and intraoperative assistance, as highlighted in recent findings. This will enhance the precision of

tumor excisions while preserving healthy tissue, ultimately improving surgical outcomes (8). Furthermore, future studies should emphasize the development of AI tools that predict postoperative complications, enabling early interventions that could significantly enhance patient care (1). As the volume of clinical data continues to expand, it becomes increasingly important to apply AI in analyzing this information effectively, thereby optimizing medical decision-making and patient management (2). Ethical considerations and clinical applicability must also remain a priority in the evolution of these AI technologies (3). By addressing these aspects, researchers can ensure the successful integration of AI in breast surgery, leading to innovations that improve patient outcomes and quality of care.

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