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## **Current Concepts and Future Perspectives in Mastectomy: Minimally Invasive Approaches and Advances in Reconstruction Techniques**

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### **Abstract:**

**Introduction and purpose:** Breast cancer remains the most common malignancy among women worldwide and represents a major cause of cancer-related mortality. Advances in oncological management have led to the development of multidisciplinary treatment strategies that integrate surgery, systemic therapy, and radiotherapy. Contemporary breast surgery increasingly incorporates reconstructive procedures using implants or autologous tissue, often supported by minimally invasive and robotic-assisted techniques. The aim of this review is to present current concepts and future perspectives in mastectomy, with particular emphasis on minimally invasive approaches and modern reconstructive methods.

**State of Knowledge:** Modern breast surgery favors breast-conserving procedures or mastectomy combined with immediate or delayed reconstruction. Both implant-based and autologous techniques demonstrate satisfactory oncological safety and favorable aesthetic outcomes. Additionally, the introduction of endoscopic and robotic-assisted approaches has enabled procedures through smaller incisions, reducing surgical trauma and potentially improving postoperative recovery and cosmetic results.

**Conclusions:** Current approaches to mastectomy combine oncological effectiveness with increasing attention to aesthetic outcomes and patient quality of life. The ongoing development of minimally invasive techniques, advances in reconstructive surgery, and the emergence of robotic technologies offer promising prospects for further improvement in surgical precision and patient satisfaction. Nevertheless, additional long-term studies and broader clinical experience are required to confirm the safety and effectiveness of these innovative approaches.

**Key Words:** Mastectomy; Breast cancer; Breast surgery; Breast reconstruction; Robotic surgery; AI

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## Introduction

Breast cancer is the most frequently diagnosed malignancy among women worldwide. According to data from 2022, it accounted for approximately 24% of all cancer diagnoses in women. In the same year, an estimated 670,000 deaths were attributed to this disease globally. Breast cancer therefore represents the leading cause of cancer-related mortality among women worldwide, whereas in Poland it ranks second in cancer-related deaths, following lung cancer [1,2]. Although breast cancer can also occur in men, it remains rare and accounts for only about 1% of all cases [3]. The global incidence of breast cancer continues to increase, posing a significant challenge for modern medicine. The most common histological type of breast cancer is adenocarcinoma, which can be classified into preinvasive and invasive forms. Among these, invasive breast cancer of no special type (IBC NST), previously referred to as invasive ductal carcinoma, is the predominant subtype and accounts for approximately 75% of all cases [4]. Other important prognostic factors include the status of estrogen and progesterone receptors as well as the expression of the human epidermal growth factor receptor 2 (HER2) [5]. One of the most aggressive subtypes is triple-negative breast cancer, which is associated with limited therapeutic options and relatively high mortality. This subtype is also more frequently observed in patients with genetically determined breast cancer related to BRCA1 and BRCA2 mutations, which are responsible for approximately 5-10% of all cases [6-8]. Table 1 summarizes both protective factors and risk factors associated with the development of breast cancer [Table 1]. Clinical manifestations that may suggest the presence of breast cancer include a painless palpable mass within the breast, skin changes such as dimpling or retraction, pathological nipple discharge, enlargement of axillary lymph nodes, and nipple inversion [9]. The diagnostic process in patients with suspected breast cancer includes medical history taking, physical examination, imaging studies - such as ultrasonography (USG), computed tomography (CT), magnetic resonance imaging (MRI), and mammography - as well as core needle biopsy followed by histopathological and molecular evaluation [10]. The management of breast cancer requires a multidisciplinary approach that integrates several therapeutic modalities in order to achieve optimal clinical outcomes. In general, four principal pillars of treatment can be distinguished: surgical treatment, radiotherapy, chemotherapy, and hormonal therapy [11]. The present article aims to present modern approaches to the surgical management of breast cancer and to discuss the latest methods applied in this field, which focus not only on optimizing

oncological outcomes but also on improving aesthetic results and minimizing long-term complications. Contemporary oncologic breast surgery increasingly incorporates breast reconstruction following mastectomy using either implant-based or autologous techniques. Moreover, the rapid development of minimally invasive surgery has enabled the introduction of endoscopic and robot-assisted procedures, opening new perspectives for improving aesthetic outcomes while reducing surgical trauma [12-14].

Table 1. Risk and Protective Factors for Breast Cancer [11]

Protective factors	<ul style="list-style-type: none"> <li>- Maintaining a healthy body weight</li> <li>- Regular physical activity</li> <li>- Limiting alcohol consumption and avoiding tobacco smoking</li> <li>- Breastfeeding</li> <li>- Early first pregnancy</li> <li>- Avoidance of hormone replacement therapy</li> </ul>
Risk Factors	<ul style="list-style-type: none"> <li>- Age (over 50 years)</li> <li>- BRCA1/BRCA2 mutations</li> <li>- Early menarche</li> <li>- Late menopause</li> <li>- Obesity</li> <li>- Previous diagnosis of breast cancer</li> </ul>

Evolution of Mastectomy Techniques

Mastectomy is a surgical procedure involving the removal of glandular tissue from one or both breasts. Depending on the clinical indications and surgical feasibility, the procedure may be partial or total and may also require the removal of additional structures such as the nipple-areola complex, overlying skin, and axillary lymph nodes [15]. Mastectomy is performed primarily for the treatment or prevention of breast cancer. Surgical techniques used in the management of breast cancer have evolved considerably over time and continue to undergo refinement. The first radical mastectomy dates back to 1889 and was performed by William Halsted. This procedure involved extensive resection of the breast gland, axillary lymph nodes, the pectoralis minor muscle, and the pectoralis major muscle. Although highly mutilating, the complications associated with radical mastectomy were considered acceptable in light of the oncological effectiveness of the procedure [16,17]. Subsequently, David Patey modified Halsted’s radical mastectomy by preserving the pectoralis major muscle. Later, John Madden introduced a further modification that preserved both pectoral muscles. This technique, known

as the modified radical mastectomy, remains an established method for removing the breast gland together with the overlying skin, nipple-areola complex, and axillary lymph nodes when breast-conserving approaches are not feasible [18,19]. However, contemporary breast surgery increasingly focuses on achieving satisfactory cosmetic outcomes while minimizing surgical morbidity. In recent decades, there has been a dynamic expansion of breast-conserving therapy (BCT) as well as mastectomy performed through limited-access approaches with either immediate or delayed breast reconstruction.

### Modern Breast Reconstruction Following Mastectomy

In contemporary breast surgery, the preferred technique for tumor removal is the aforementioned breast-conserving therapy (BCT). Current indications for this approach include a biopsy-confirmed diagnosis of ductal carcinoma in situ (DCIS) or invasive breast cancer suitable for surgical treatment, in which negative surgical margins can be achieved while maintaining a satisfactory cosmetic outcome [20,21]. However, in certain clinical situations, total mastectomy remains the recommended therapeutic option. For instance, this procedure may be indicated in cases of multifocal breast cancer, inability to obtain clear surgical margins, inflammatory breast cancer, contraindications to radiotherapy, the presence of pathogenic BRCA1/2 mutations, or when the patient declines breast-conserving treatment [22]. It should be emphasized that simple mastectomy is an invasive procedure in which, in addition to the glandular tissue, the overlying skin, the nipple-areola complex, and the fascia of the pectoralis major muscle are removed. As a result, the procedure leaves a visible scar and may lead to significant asymmetry of the chest wall. For many women, the loss of the entire breast may substantially reduce quality of life, self-esteem, and the sense of femininity. In response to these limitations, modern oncologic breast surgery has increasingly adopted techniques such as subcutaneous and nipple-sparing mastectomy, which allow preservation of the nipple-areola complex and enable either immediate or delayed breast reconstruction [23,24]. The following sections describe the principal methods used in reconstructive breast surgery within the context of oncologic treatment.

#### **3. 1 Breast Reconstruction with Implants**

Implant-based breast reconstruction is a surgical procedure performed to restore the natural contour of the breast following its removal during breast cancer treatment or, in selected cases, as part of risk-reducing surgery in patients carrying BRCA1/2 mutations [25]. In addition to recreating breast shape, filling the space left after removal of the mammary gland helps maintain symmetry of the chest wall. This technique can be applied in many patients with breast cancer, except for those who have previously undergone radiotherapy. It is also generally considered less invasive than autologous tissue reconstruction described below [26,27]. Implant-based reconstruction may be performed simultaneously with mastectomy (immediate reconstruction) or as a delayed procedure, for example after completion of adjuvant therapy such as chemotherapy. The procedure can be carried out as a one-stage or two-stage reconstruction. In one-stage reconstruction, the final implant - most commonly a silicone implant - is placed immediately. This approach is feasible when an adequate amount of skin remains after mastectomy. In contrast, a two-stage reconstruction with a tissue expander is used when the available skin envelope is insufficient or after extensive resection. In this approach,

placement of the definitive implant is preceded by insertion of a tissue expander designed to gradually prepare the tissues to accommodate the final prosthesis. The expander is progressively filled with saline, allowing gradual expansion of the skin and soft tissues and ultimately creating sufficient space for placement of the permanent implant [28,29]. The implant may be positioned either beneath the pectoralis major muscle (subpectoral placement) or above it, directly under the skin (prepectoral placement). Subpectoral placement offers advantages such as better concealment of the implant and a lower risk of capsular contracture. However, it is associated with longer recovery time, greater postoperative discomfort, and the potential for implant displacement during contraction of the pectoral muscles. Prepectoral placement, in contrast, is associated with reduced postoperative pain and a shorter recovery period, although it may carry a higher risk of visible implant rippling and a slightly increased risk of infection [30,31]. To improve contour and cosmetic outcomes, autologous fat grafting may be used to provide additional volume in selected areas requiring soft tissue augmentation [32]. It is also important to consider the limitations of implant-based reconstruction, particularly in unilateral procedures, where postoperative asymmetry may occur and additional corrective surgery on the contralateral breast may be required. Patients with adequate soft tissue coverage and no history of radiotherapy are considered ideal candidates for implant-based reconstruction. Meta-analyses confirm that implant-based breast reconstruction is not only oncologically safe and effective but also provides favorable aesthetic outcomes. Importantly, this method should not be regarded as a second-line option; when appropriate indications are present, it may serve as a definitive therapeutic approach that preserves physical health, quality of life, and a patient's sense of femininity [33].

### **3. 2 Breast Reconstruction Using Autologous Tissue**

Autologous breast reconstruction using tissue flaps represents the second major approach to breast restoration after mastectomy, alongside implant-based techniques. This method relies on advanced oncoplastic and microsurgical procedures and requires a highly experienced surgical team. In autologous reconstruction, the surgeon harvests tissue from another region of the patient's body and uses it to recreate the breast removed during mastectomy. Potential donor sites include the abdomen, back, buttocks, and thighs [34-39]. The specific donor areas commonly utilized in reconstructive breast surgery are summarized in Table 2 [Table 2]. During the procedure, skin, adipose tissue, muscles, and blood vessels are harvested and subsequently anastomosed to restore vascular supply to the reconstructed breast. Over recent decades, these techniques have undergone substantial development, largely due to advances in microsurgical vascular techniques that enable effective breast reconstruction while reducing the risk of flap necrosis. Modern reconstructive surgery aims to employ a wide range of therapeutic strategies and tailor treatment to the individual needs and anatomical conditions of each patient [40]. Currently, the deep inferior epigastric perforator (DIEP) flap is considered the most frequently used technique and the gold standard in autologous breast reconstruction. Historically, the transverse rectus abdominis myocutaneous (TRAM) flap was widely regarded as the standard approach; however, its use has declined in favor of the DIEP flap, which preserves the rectus abdominis muscle and is associated with a lower rate of donor-site complications [35]. Emerging reconstructive options such as the lumbar artery perforator (LAP) flap and the profunda artery perforator (PAP) flap are gradually gaining attention in reconstructive breast surgery. This trend is partly related to the limitations of the DIEP flap donor site, which requires an adequate amount of lower abdominal tissue. Consequently, LAP and PAP flaps provide alternative solutions for patients who are not suitable candidates for abdominal-based

reconstruction. Nevertheless, the LAP flap is associated with certain limitations, including technical complexity and the requirement for intraoperative repositioning of the patient [41]. One of the main advantages of autologous reconstruction is the ability to achieve a more natural aesthetic outcome and a tissue consistency similar to that of a natural breast. This technique is also often preferred in patients who require postoperative radiotherapy and is associated with a lower risk of infection compared with implant-based reconstruction. However, autologous breast reconstruction is considerably more complex than implant placement and may be associated with complications such as partial flap necrosis, wound dehiscence, hematoma formation, or donor-site hernia [42]. Due to the limited number of high-quality studies, it is currently not possible to establish universally accepted guidelines for autologous breast reconstruction following mastectomy. Continued development of minimally invasive and robotic-assisted techniques may further advance this field of surgery; however, their effectiveness requires further investigation and long-term clinical evaluation.

Table 2. Common donor sites and flap options in autologous breast reconstruction [34-39]

<b>Anatomical donor site</b>	<b>Flap type</b>	<b>Description</b>
Abdomen	DIEP	Deep inferior epigastric perforator flap
	TRAM	Transverse rectus abdominis myocutaneous flap
	SIEA	Superficial inferior epigastric artery flap
Back	LD	Latissimus dorsi flap
	LAP	Lumbar artery perforator FLAP
Thigh	TUG/VUG/DUG	Transverse/vertical/diagonal upper gracilis flap
	PAP	Profunda artery perforator flap
Buttocks	SGAP/IGAP	Superior/inferior gluteal artery perforator

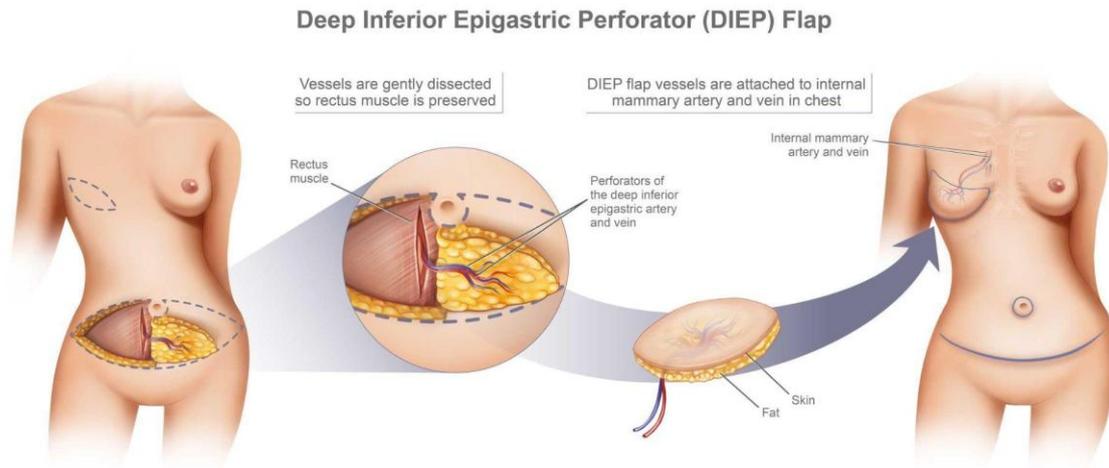


Figure 1. DIEP flap breast reconstruction [43]

## Minimally Invasive Approaches in Mastectomy

### 4. 1 Endoscopic (Laparoscopic) Breast Surgery

Laparoscopic surgery has traditionally been applied primarily in abdominal, gynecological, and thoracic procedures. Only in recent years has technological progress enabled surgeons to overcome limitations related to breast anatomy and the restricted operative space within the breast region. The introduction of a 40-mm port allowing simultaneous use of laparoscopic instruments and an optical system has made it possible to perform mastectomy through a small axillary incision. This approach represents a significant advancement, as it enables an extensive surgical procedure to be performed through a minimal access route, resulting in reduced tissue trauma, improved wound healing, more favorable cosmetic outcomes, and faster postoperative recovery for patients [44,45]. A study conducted in Korea compared conventional subcutaneous mastectomy with an endoscopic technique and demonstrated that the minimally invasive approach is both feasible and safe. Importantly, the procedure allowed the achievement of negative surgical margins while providing superior cosmetic results and a smaller, less conspicuous scar [46]. In addition, increasing attention has been directed toward the possibility of performing mastectomy simultaneously with breast reconstruction - either implant-based or autologous - through an axillary approach. Implant-based breast reconstruction performed using laparoscopic techniques has been shown to be feasible and effective; however, it requires a highly experienced surgical team, specialized equipment, and a longer operative time, which is why it has not yet become a standard procedure in the surgical treatment of breast cancer [47]. Attempts have also been made to perform reconstruction using autologous tissue, including the latissimus dorsi flap harvested through minimally invasive approaches. Studies have demonstrated the feasibility and effectiveness of this procedure, whose key innovation compared with conventional techniques lies in avoiding visible scars on the back and lateral chest wall. Although this technique appears promising, further research and broader surgical training are necessary before it can be widely adopted as a modern and innovative therapeutic strategy [48].

## 4. 2 Robot-Assisted Breast Surgery

The use of robotic-assisted techniques may represent a new frontier in oncologic breast surgery. Similar to conventional laparoscopy, one of the principal advantages of this innovative approach is an improved cosmetic outcome achieved through minimal access and smaller postoperative scars, typically measuring approximately 3.5 cm compared with around 7 cm in open procedures [49]. In principle, robotic surgery is intended for patients eligible for nipple-sparing mastectomy with the possibility of immediate breast reconstruction. Robotic surgery also offers several advantages for the operating surgeon. The procedure is performed from a console in a seated position, which may reduce physical fatigue during prolonged operations and eliminates the need for sustained manual force to manipulate and retract tissues. This ergonomic benefit is considered an additional advantage compared with conventional laparoscopy [50]. Furthermore, robotic systems allow elimination of natural hand tremor and provide improved access to anatomical structures that may be difficult to reach using traditional techniques. Another important feature is the advanced optical system, which provides a magnified, high-definition view of the operative field, enabling precise visualization of tissues and reducing the risk of inadvertent injury to structures that may not be clearly visible without magnification [51]. Despite these advantages, robotic breast surgery remains an emerging concept and faces several challenges. Currently, such procedures constitute only a small proportion of oncologic breast surgery, and further large-scale studies involving extensive patient cohorts are required to evaluate the long-term safety, effectiveness, and complication rates associated with this approach. Although existing studies have produced promising results, the available evidence remains insufficient to conclusively confirm consistent oncologic safety and reliable achievement of negative resection margins with robotic techniques [52,53]. Moreover, robotic surgery is unlikely to play a significant role in breast-conserving therapy, where conventional open techniques are expected to remain the standard approach [52]. Additional limitations include the high cost of robotic systems, expenses related to their maintenance and use, and the need for specialized training of surgical teams. Nevertheless, as the adoption of this technology continues to expand, it is anticipated that standardized guidelines will be developed and higher-quality scientific evidence will emerge to further clarify its safety and clinical effectiveness [54].

### Future Perspectives in Mastectomy and Breast Reconstruction

Given the substantial burden of breast cancer as a major public health concern, continuous research is being conducted to improve existing treatment strategies and to develop novel therapeutic approaches. Contemporary - and increasingly future-oriented - management of breast cancer is based on a multidisciplinary model that integrates the collaboration of specialists in surgery, medical oncology, radiation oncology, pathology, physiotherapy, and psycho-oncology. The appropriate combination of surgical treatment with chemotherapy, radiotherapy, and hormonal therapy enables optimization of therapeutic outcomes and improvement of patient prognosis. Increasing emphasis is also placed on individualized treatment strategies that consider not only the biological characteristics of the tumor but also the needs, capabilities, and expectations of each individual patient [55]. The development of oncoplastic breast surgery has further shifted the focus of treatment beyond radical tumor removal toward minimizing the long-term consequences of therapy and achieving optimal functional and aesthetic outcomes. Ensuring satisfactory breast reconstruction after mastectomy should therefore be considered an integral component of comprehensive cancer care and should

be widely accessible to all patients who meet the appropriate clinical indications. Numerous studies have demonstrated that breast reconstruction following mastectomy has a significant positive impact on patients' psychological well-being, self-esteem, and sense of femininity [56]. Attention should also be drawn to the minimally invasive techniques described above, including procedures assisted by robotic systems, whose further development may contribute to reduced surgical trauma, improved cosmetic outcomes, and enhanced ergonomic conditions for surgeons [51]. Another emerging direction in breast cancer management involves the use of artificial intelligence (AI) to visualize potential reconstructive outcomes in women undergoing mastectomy. Recently developed AI-based algorithms enable the prediction of postoperative reconstructive results for individual patients, allowing for more precise case analysis and improved preoperative planning tailored to specific clinical scenarios. The effectiveness of such algorithms has been evaluated using photographic datasets of patients' breasts obtained both before and after reconstructive procedures. The AI model was trained to generate predicted postoperative images based on preoperative photographs, and the simulated results were subsequently compared with the actual surgical outcomes. The study demonstrated a high degree of concordance between AI-generated visualizations and real postoperative results, suggesting that this technology may represent a promising new tool for clinical decision-making and surgical planning in oncologic breast surgery [57,58].

## Conclusions

The history of breast cancer surgery illustrates how profoundly the approach to treatment has evolved over time. When Halsted introduced the concept of radical mastectomy, the primary focus was almost exclusively on complete tumor eradication, with little consideration given to long-term quality of life or aesthetic outcomes. Contemporary oncoplastic surgery has largely moved away from this paradigm, emphasizing precise and tissue-sparing procedures that combine oncological effectiveness with minimization of scarring, preservation of cosmetic appearance, and protection of the patient's psychological well-being. Currently, the standard management of breast cancer is based on a multidisciplinary approach integrating surgery, chemotherapy, radiotherapy, and hormonal therapy, with therapeutic decisions increasingly tailored to the individual needs and preferences of each patient. Advances in oncoplastic techniques have enabled the widespread use of breast-conserving therapy (BCT), skin-sparing and nipple-sparing mastectomy, as well as immediate or delayed reconstruction using either implants or autologous tissues. Moreover, minimally invasive approaches (including endoscopic and robotic techniques) allow complex procedures to be performed through small axillary incisions, which significantly improves cosmetic outcomes and may accelerate postoperative recovery. Breast reconstruction, whether implant-based or autologous, has become an integral component of modern oncologic treatment. Nevertheless, each of these methods carries specific limitations, including potential postoperative complications, anatomical constraints, and the requirement for highly specialized surgical expertise. Not all patients are suitable candidates for advanced reconstructive procedures, and the availability of specialized centers equipped with the necessary technology and trained personnel capable of performing laparoscopic or robotic-assisted surgeries remains limited. At the same time, rapid developments in artificial intelligence, surgical planning systems, and simulation tools capable of predicting individualized reconstructive outcomes are opening new possibilities for personalized treatment strategies. Progress in microsurgery and autologous tissue reconstruction techniques further expands the range of available therapeutic options. As a result, patients are increasingly able to participate in shared decision-making regarding their treatment,

and the concept of “tailor-made” surgical planning is gradually becoming a reality, enabling oncological objectives to be achieved while preserving aesthetic outcomes and overall quality of life. In conclusion, breast and oncoplastic surgery still have significant potential for further development. Modern treatment approaches extend beyond the goal of cancer eradication alone and increasingly encompass the preservation of psychological well-being, physical appearance, and individualized patient-centered care. Despite existing limitations - such as the need for larger clinical studies, a limited number of highly trained specialists, and the potential risks associated with reconstructive procedures - the future of breast surgery remains promising. The gradual integration of advanced technologies may further enhance the quality of care and improve patient satisfaction in the years to come.

## **Disclosure**

### **Author’s Contribution**

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