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Review Article

A review of different breast reconstruction methods

Yuhang Song, Jiahui Zeng, Xingchen Tian, Hongmei Zheng*, Xinhong Wu*

*Department of Breast Surgery, Hubei Cancer Hospital, Tongji Medical College, Huazhong University of Science and Technology, Hubei Provincial Clinical Research Center for Breast Cancer, Wuhan Clinical Research Center for Breast Cancer, No. 116 Zhuo Daoquan South Road, Wuhan 430079, Hubei, China. *Equal contributors.*

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Abstract: Breast reconstruction is necessary for the comprehensive treatment of breast cancer. For successful breast reconstruction, the timing of surgery and the surgical methods used are vital. The methods of breast reconstruction can be divided into implant-based breast reconstruction (IBBR) and autologous breast reconstruction (ABR). With the development of acellular dermal matrix (ADM), IBBR has become more common in clinical practice. However, the choice for the position in which the implant should be placed (prepectoral or subpectoral) and the use of ADM is currently controversial. We summarized the differences in indications, complications, advantages, disadvantages, and prognosis between IBBR and ABR. We also compared the indications and complications of different flaps in ABR and found that the LD (latissimus dorsi) flap is suitable for Asian women who have a low body mass index (BMI) and a low incidence of obesity, while the DIEP (deep inferior epigastric perforator) flap can be used in patients with severe breast ptosis. In conclusion, immediate breast reconstruction with an implant or expander is the primary method, as it causes lesser scarring and requires a shorter time compared to ABR. However, for patients with severe breast ptosis or reluctant to receive an implant, ABR can be performed for a satisfying cosmetic result. Indications and complications of different flaps in ABR are also inconsistent. Surgeons should make surgical plans based on the preferences and conditions of each patient. In the future, breast reconstruction methods need to be further refined, and minimally invasive and personalized approaches need to be implemented to provide more benefits to patients.

Keywords: Breast cancer, implant-based breast reconstruction (IBBR), autologous breast reconstruction (ABR), acellular dermal matrix (ADM), deep inferior epigastric perforator (DIEP) flap, transverse rectus abdominis myocutaneous (TRAM) flap, latissimus dorsi (LD) flap

Introduction

Breast cancer is the most common malignancy in women worldwide [1]. A comprehensive treatment based on surgery is generally used for treating breast cancer. However, patients after surgery are often depressed and prone to psychological trauma due to poor breast shape. To improve the quality of life of patients after mastectomy, breast reconstruction can be performed after breast cancer surgery. The percentage of patients that underwent reconstruction after breast cancer surgery increased from 26.94% in 2005 to 43.30% in 2014 [2]. For a successful breast reconstruction surgery, the timing of reconstruction and surgical methods are the key points [3]. In this review, we discussed the timing of breast reconstruction and compared different reconstruction methods.

Timing of breast reconstruction

The timing of breast reconstruction can be divided into immediate, delayed, or delayed-immediate breast reconstruction [4]. Immediate breast reconstruction refers to breast reconstruction performed by breast surgeons and plastic surgeons during mastectomy. Delayed breast reconstruction is performed several months or years after mastectomy, when the patient's body has recovered from the side effects of radiotherapy and chemotherapy or when the disease is stable with little possibility of recurrence and metastasis. The delayed-immediate breast reconstruction process involves the placement of an expander as a bridge during mastectomy until it is replaced by implants or autologous tissue at the end of treatment [5].

Generally, patients who are eligible for immediate breast reconstruction are diagnosed with stage I breast cancer; they also have a good cancer prognosis, a negative sentinel lymph node, and no requirement for axillary lymphadenectomy surgery or radiotherapy treatment [6]. A systematic review and meta-analysis showed that immediate breast reconstruction generally increases the risk of complications compared to delayed reconstruction [7].

Some patients with stage II and most patients with stage III breast cancer undergo postmastectomy radiotherapy (PMRT), and current guidelines recommend delayed or delayed-immediate breast reconstruction for this category of patients [3, 6]. Delayed reconstruction is considered to be better for patients who are considered for PMRT, as the immediate reconstruction could influence not only the aesthetic outcome but also the delivery of radiotherapy [8, 9]. However, recent studies have shown that immediate breast reconstruction is safe for patients with locally advanced breast cancer and does not affect survival, cancer recurrence rates, or the use of adjuvant therapy [10, 11]. A study also reported that compared to delayed breast reconstruction, immediate breast reconstruction after PMRT does not result in higher rates of complications and requires fewer revisions [12].

Implant-based breast reconstruction (IBBR)

IBBR is the most common breast reconstruction method in the world, and its application is increasing [13]. In a longitudinal trend analysis of the National Inpatient Sample database from 1998-2008, the rate of implant reconstructions increased by 11% yearly [14]. A seven-year population-based cohort study also showed that between 2007 and 2014, immediate implant reconstruction increased from 30% to 54% [15]. This technique is often preferred by patients who want to avoid scars and pain in the chest region, such as the abdomen and back. Capsular contracture and implant failure are common complications of breast reconstruction with implants and expanders (e.g., rupture, deflation, and malposition) [16].

Prepectoral and subpectoral IBBR

Based on the position of the implant, IBBR can be divided into prepectoral and subpectoral IBBR [17]. Prepectoral IBBR avoids the separation of the pectoralis major, reduces postoperative pain, and facilitates early recovery and hospital discharge, with lower risks of animation as the implant is not placed below the muscle [18-21]. Prepectoral IBBR has a lower incidence rate in capsular contracture, animation deformity, infection, hematoma, and delayed wound healing than subpectoral IBBR [22]. However, no significant differences are present in skin flap necrosis, seroma, implant loss, reoperation, and the duration of drainage between the two groups. Sbitany et al. reported that the difference in the complication rate between the prepectoral and subpectoral approaches was not significant (17.9% vs. 18.8%; P = 0.49) [23]. A prospective cohort study with 40 patients compared prepectoral and subpectoral IBBR performed preferably in one stage and found no significant differences in the mean short-term pain scores (1.5 vs. 1.5; P = 0.45) and the mean mid-term BREAST-Q (health-related quality of life scales and satisfaction scales) scores (72 vs. 71; P = 0.81) [19]. To summarize, the differences in complication rates and patient satisfaction between prepectoral and subpectoral IBBR are still controversial.

Should acellular dermal matrix (ADM) be used?

With the development of ADM and mesh, many studies have recommended prepectoral IBBR [24-27]. The major benefits of using an ADM include better initial breast contouring, lower risk of capsular contracture after implant insertion, and consistent sustained positioning of the reconstructed breast [28]. Vardanian et al. compared 123 patients with ADM reconstruction and 80 patients without ADM reconstruction and found that the capsular contracture rate with ADM was 3.8%, and without ADM was 19.4% [29]. However, a retrospective review reported that the complication rate was 20.3% in the ADM group in 501 patients (990 breasts), as determined by the complication analysis [30]. The researchers also found that overall complications and major complications were more frequent in the ADM group. An RCT-based study also found that compared to IBBR without ADM, IBBR with ADM exhibited more overall complications and reoperations (95% CI: 0.01 to 0.32, P = 0.070), and the patients had a significantly higher risk of developing problems

Table 1. Comparison between IBBR and ABR

Methods	Indications	Complications	Advantages	Disadvantages	Prognosis
IBBR	patient preference and good soft tissue	capsular contracture and implant failure	easy to operate, low cost, and one incision	breast asymmetry and poor aesthetic effect	recurrence (909 days)
ABR	patient preference, failed implant, and severe soft tissue damage	fat necrosis, venous congestion, donor site bulging/hernia, and seroma	excellent long-term results, natural appearance, natural feel and best opportunity for sensory restoration	high cost, long operation time, two incisions, and long learning curve	recurrence (1246 days)

Notes: IBBR, implant-based breast reconstruction; ABR, autologous breast reconstruction.

related to wound healing (P = 0.013) [31]. An RCT-based study reported that the reoperation rate of immediate IBBR with ADM was lower than that of conventional IBBR without ADM; also, IBBR with ADM was not superior regarding higher health-related quality of life (QoL) or patient-reported cosmetic outcomes [32]. Although many researchers recommend using ADM, the complications caused by ADM are still debated.

Autologous breast reconstruction (ABR)

ABR provides the benefits of excellent long-term results, natural appearance and feel, and the best opportunity for sensory restoration [33]. A systematic review and meta-analysis showed that aesthetic satisfaction (mean difference [MD]: 8.51; 95% CI: 10.70 to 6.33; P < 0.001) and satisfaction with the entire reconstructive treatment (MD: 6.56; 95% CI: 9.97 to 3.14; P < 0.001) were significantly better after ABR than those after IBBR [34]. Also, the difference in the time from surgery to recurrence between the autologous tissue group (1,246 days) and the implant group (909 days) was significant (P = 0.021) [35]. ABR might have higher health costs than IBBR [34, 36, 37]. The indications, complications, advantages, disadvantages, and prognosis of IBBR and ABR are presented in **Table 1**.

Autologous tissue mainly includes the deep inferior epigastric perforator (DIEP) flap, the transverse rectus abdominis myocutaneous (TRAM) flap, the latissimus dorsi (LD) flap, other flaps, and autologous fat [38]. The most common flap-related complication following autologous reconstruction is the necrosis of fats. Other complications following abdominal-based breast reconstruction include abdominal wall bulging/hernia, dehiscence, delayed wound healing, infection, hematoma, and seroma [39]. The indications and complications of different flaps are presented in **Table 2**, and the characteristics of all flaps are described in the following sections.

Deep inferior epigastric perforator (DIEP) flap

The DIEP flap is cut with a vessel from a penetrating branch of the inferior abdominal wall artery as the tip without the need to remove the rectus abdominis muscle [40]. Indications for using abdominal-based flaps (like the DIEP or the TRAM flap) for breast reconstruction often include patient's preference, severe soft tissue damage (secondary to radiation therapy), and even failed implant reconstruction [41]. It preserves the relative integrity of the rectus abdominis muscle, thus preventing serious damage and destruction of the rectus abdominis muscle like the TRAM flap [42]. It not only decreases abdominal wall complications but also facilitates an abdominoplasty effect, which is a further improvement of the free rectus abdominis muscle flap [43, 44]. An RCT-based study reported that satisfaction with breasts, measured with BREAST-Q, was significantly higher in patients who underwent reconstruction with the DIEP flap than in patients who were administered an expander implant [37].

Venous congestion is the most common vascular complication of DIEP flaps. It usually occurs in flaps distal to the vascular tip and may lead to the necrosis of flaps in severe cases [45]. In such cases, performing a second venous anastomosis between the superficial inferior epigastric vein and a recipient vein can reduce venous congestion and related complications in the DIEP flaps during breast reconstruction [46]. Some plastic surgeons usually perform Doppler ultrasound examinations, computed tomography angiography (CTA), or infrared thermography to locate the penetrating vessels and reasonably assess the donor-recipient vascular anastomosis before surgery [47]. Preoperative

Table 2. Comparison of different flaps

Autologous flaps	Indications	Complications
DIEP	patient preference, failed implant, and severe soft tissue damage	fat necrosis (high), abdominal bulging/hernia (low), and venous congestion (high)
SIEA		abdominal bulging/hernia (low), wound infection (high)
TRAM		fat necrosis (low in fTRAM), abdominal bulging/hernia (high in pTRAM and low in fTRAM), and flap loss (high in pTRAM)
LD	patient preference, insufficient tissue volume, impaired abdominal blood supply, a history of abdominal surgery, and postoperative deformities that need correction	seroma (high), shoulder pain, and dysfunction (high)
TAP		seroma (low), shoulder pain, and dysfunction (low)

Notes: "high" or "low" showed in this table refers to the complication rates compared with the other flaps at the same site. DIEP, deep inferior epigastric perforator; SIEA, superficial inferior epigastric artery perforator; TRAM, transverse rectus abdominis myocutaneous; LD, latissimus dorsi; TAP, thoracodorsal artery perforator.

CTA can identify atypical venous connections, thus increasing the chances of flap survival and decreasing venous congestion in patients considering DIEP breast reconstruction [48]. An RCT-based study reported that the flap dissection time was significantly shorter in the CTA group than in the group without CTA (150.8 ± 17.8 vs. 184.7 ± 25.1 min, $P < 0.001$) with equivalent postoperative outcomes [49]. Another common complication of DIEP procedures is fat induration and necrosis [50]. An RCT-based study reported that fluorescent angiography with indocyanine green could help remove the poorly vascularized tissues of the DIEP flap, which in turn can significantly decrease the incidence of fat necrosis without reducing the size of the flaps [51].

Transverse rectus abdominis myocutaneous (TRAM) flap

The TRAM flap is a donor flap with abundant tissue and good blood flow and is easy to operate. As mentioned earlier, it is similar to the DIEP flap. It allows for a natural sagging of the reshaped breast that suits the aesthetic standards, and the survival rate of the flap is high. After flap excision, the donor skin tissue can be pulled together and sutured. In patients with abdominal wall obesity, breast reconstruction, and abdominal wall contouring can be performed simultaneously using this method. TRAM flaps can be categorized as a pedicled TRAM (pTRAM) flap, free TRAM (fTRAM) flap, or muscle-sparing free TRAM (MS-TRAM) flap based on whether they are pedicled and whether they retain muscles. Because the pTRAM flap is not inferior to the fTRAM flap in terms of satisfaction and is associated with more frequent complications, it is being replaced by the fTRAM flap and the DIEP flap [52, 53]. Compared to the patients in the DIEP flap group, those in the pTRAM flap group were more likely to require abdominal closure with mesh (44.2% vs. 8.1%; $P < 0.001$); 21.2% of patients in the pTRAM flap group had a postoperative abdominal bulge and/or hernia versus only 3.1% of the patients in the DIEP flap group [54]. Although pTRAM flaps are associated with a greater risk of flap loss, they are still a suitable option when microsurgery is unavailable [55, 56]. Therefore, they might be used in developing countries that lack facilities and are limited by expenses [52].

Compared to the DIEP flap, the fTRAM flap was found to have a lower incidence of flap fat necrosis, hematoma, and total thrombotic events but a higher risk of abdominal bulging/hernia [57]. A systematic review and meta-analysis reported that obesity increased the risk of total flap loss (risk ratio [RR]: 1.68; 95% CI: 0.85 to 3.33), partial flap loss (RR: 2.26; 95% CI: 1.01-5.02), abdominal bulging or hernia (RR: 1.72; 95% CI: 1.00-2.95), and overall abdominal complications (RR: 1.53; 95% CI: 1.10-2.14) [58]. The MS-TRAM or the DIEP flap should be recommended for obese patients to decrease the risk of abdominal bulging/hernia [55]. The MS-TRAM flap is a reliable method of autologous breast reconstruction with minimal donor-site morbidity compared to the conventional TRAM flap [58, 59]. Delay of the TRAM flap can increase flow and decrease resistance in the superior epigastric pedicle with the dilation of choke vessels, resulting in a decrease in flap

ischemia without an increase in complications [60].

Latissimus dorsi (LD) flap

The LD flap has a good tissue donor area, a reliable blood supply, and is easy to operate. It is a more suitable breast reconstruction method for patients with insufficient tissue volume, impaired abdominal blood supply, a history of abdominal surgery, and postoperative deformities that need correction. It can be used, in combination with fat tissue or implants, not only for patients with small or medium-sized breasts but also for those with large breasts. Compared to the DIEP flap, the LD flap with a lesser volume is more suitable for Asian women with a lower body mass index (BMI) and low incidence of obesity [61]. For patients with large breasts, the LD flap with immediate fat transfer (LIFT) facilitates single-stage breast reconstruction with high-volume fat transfer to provide sufficient volume [62, 63]. Performing this technique is easy, and it requires a shorter operation time than the DIEP flap because only a few large vessels are present between the posterior chest wall and the muscle [64]. An RCT-based study reported that in patients who underwent radiation therapy, the frequencies of short-term complications were similar for the DIEP flap and the LD flap [65]. The most common complication is donor-site seroma, which occurs in 21% to 79% of cases [66]. The use of quilted donor sites can significantly reduce the incidence of donor site seroma [61, 67]. Whether harvesting the LD flap results in a significant functional deficit at the shoulder region and upper extremity is controversial [68]. Brackley et al. reported that LD breast reconstruction causes minimal damage to the shoulder joint and does not significantly affect its function [69]. Recently, Rindom et al. reported that harvesting the LD flap increases the risk of shoulder-function impairment, chronic pain, and difficulty in performing regular activities [70]. Additionally, the need to change the patient's position once or twice during the operation also increases the time required and the difficulty of the process. The LD flap can also be harvested with only a minor scar and a good appearance using modern techniques, such as endoscopic and robotic procedures [71, 72]. But such modern techniques are not widely used, especially in developing countries, and these techniques have a steep learning curve [73].

Other flaps

The pedicled thoracodorsal artery perforator (TAP) flap is a relatively new method that requires the transfer of autologous tissue [74]. The TAP flap is a modification of the LD flap and can be used for partial or complete breast reconstruction [75]. The TAP flap has certain advantages due to a lower rate of donor site-related morbidity than the classic LD flap, which is generally considered to be a working horse flap for breast reconstruction [76]. An RCT-based study investigated differences in shoulder-related morbidity after delayed breast reconstruction using either the LD flap or the TAP flap [70]. Compared to the patients who underwent reconstruction using LD flaps, those who underwent reconstruction using TAP flaps were less likely to experience shoulder-related pain and had better shoulder function one year after reconstruction. The TAP flap is also associated with a lower risk of seroma formation compared to the LD flap [77]. Another RCT-based study reported that the TAP flap is a more cost-effective method of breast reconstruction than the LD flap [78].

The superficial inferior epigastric artery perforator (SIEA) flap is an abdominal free flap based on the superficial system. It shows the least donor-site morbidity because the dissection is only subcutaneous [79]. The SIEA flap was shown to have a low risk of donor site hernia/bulging but a high risk of wound infection [57]. The widespread acceptance of the SIEA flap has been limited by technical difficulties with harvest and inset, given inconsistencies in the anatomical vessel, a reduction in the pedicle size, and the tendency of vessel spasm [80].

Autologous fat grafting

Implants are generally inserted to improve the volume, but as they have many associated problems, the use of fat grafting has become popular [81]. In this technique, fat is collected from fat-rich areas of the body, such as the thighs, abdomen, and buttocks, through negative pressure liposuction. Then, the fat particles are purified and filled evenly in the depressed areas of the breasts [82]. The combined implantation of the implant and autologous-fat gran-

ule for breast reconstruction after a radical mastectomy is a simple operation and has better aesthetic outcomes and safety. It satisfies the aesthetic needs of patients with resected lesions, and it does not alter the surgical effects of modified radical mastectomy [83].

Development trend and prospective

The modern approach to breast reconstruction is a synthesis of the development of surgical techniques, advancement in material technologies, and focus on providing care to patients through a team-oriented approach [39]. Minimally invasive techniques, such as endoscopic surgery and robot-assisted surgery, might replace traditional surgery. For IBBR, the reduction of implant-related complications (implant exposure, capsular contracture, poor feeling, etc.) and the recovery of the sensory function of the reconstructed breast are future concerns. Breast reconstruction requires the cooperation of the teams involved in breast surgery and plastic surgery to develop a more personalized, minimally invasive, and refined plan based on the patient's conditions. With the development of tissue engineering technology, stable construction of tissue-engineered breasts with a large volume and intact physiological functions might be possible.

Conclusion

For patients with stage I breast cancer who do not require postmastectomy radiotherapy (PMRT), the timing of reconstruction is determined based on the patient's status and preference. For patients with stage II and stage III breast cancer who require PMRT, immediate reconstruction was not prioritized in the past, but now it is considered that immediate reconstruction is also safe, and autologous reconstruction is preferred. However, the position of implant placement (prepectoral or subpectoral) and the importance of ADM are still controversial. The risks and benefits should be thoroughly evaluated while making the treatment plan for patients. IBBR and ABR have differences in indications, complications, costs, and prognosis. The indications and complications of different flaps in ABR are also significantly different. In conclusion, immediate breast reconstruction with implants or expanders is the primary method, as the method involves less scarring and a shorter operation time compared to ABR. However, for patients with severe breast ptosis or those who are reluctant to receive an implant, ABR can achieve a very satisfying cosmetic result. Patients should be fully informed about the differences between these breast reconstruction methods, and surgical plans should be made based on the preferences of patients and their conditions. Breast reconstruction methods need to be refined, and minimally invasive and personalized approaches need to be developed to provide more benefits to patients.

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Disclosure of conflict of interest

None.

Address correspondence to: Drs. Xinhong Wu and Hongmei Zheng, Department of Breast Surgery, Hubei Cancer Hospital, Tongji Medical College, Huazhong University of Science and Technology, Hubei Provincial Clinical Research Center for Breast Cancer, Wuhan Clinical Research Center for Breast Cancer, No. 116 Zhuo Daoquan South Road, Wuhan 430079, Hubei, China. Tel: +86-18602726300; Fax: +86-02787670290; E-mail: wuxinhong_9@sina.com (XHW); Tel: +86-18971624606; E-mail: zhenghongmeicj@sina.com (HMZ)

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