Curr Surg Rep (2020) 8:11
https://doi.org/10.1007/s40137-020-00256-4

Breast Reconstruction Following Breast Conserving Surgery: A Review

Karri Adamson[1] · David D. Rivedal[1] · Erin L. Doren[1]

Published online: 22 May 2020

Abstract
Purpose of Review Approximately one-third of women who have breast conserving surgery (BCS) will develop a cosmetic deformity following adjuvant radiation. Here we review current surgical techniques for breast reconstruction following BCS and review the evidence for their safety and efficacy.
Recent Findings Breast reconstruction can be performed in three settings following BCS: at the time of the partial mastectomy, following partial mastectomy prior to radiation, and delayed following completion of adjuvant radiation. Current options for reconstruction include fat grafting, tissue rearrangement and reduction techniques, as well as tissue replacement with local, regional, and free tissue transfer. Patients who have immediate reconstruction report the highest satisfaction.
Summary Breast reconstruction following BCS has been shown to improve patient satisfaction and cosmetic outcomes without an increased risk of complications or cancer recurrence. All patients considering BCS should be offered a consultation with a plastic surgeon to review their surgical options.

Keywords Breast cancer · Breast conservation surgery · Lumpectomy · Partial mastectomy · Oncoplastic surgery · Breast reconstruction

This article is part of the Topical collection on *Plastic Surgery*.

✉ Karri Adamson
kadamson@mcw.edu

[1] Department of Plastic Surgery, Medical College of Wisconsin, 1155 N. Mayfair Rd, Wauwatosa, WI 53226, USA

Introduction

Breast cancer is the most common non-skin cancer diagnosis in women and will affect 1 in 8 over their lifetime [1]. Large, randomized controlled trials have confirmed equivalent long-term survival in women having breast conserving surgery (BCS) plus radiation compared to mastectomy [2, 3]. There is also high-quality data that shows improved overall survival and disease-specific survival for patients with early stage breast cancer who received BCS compared to mastectomy [4, 5]. Nationally, BCS rates range from 30 to 70% of patients with early stage breast cancer [4, 6]. A recent study investigating the national trends using National Surgical Quality Improvement Program (NSQIP) data has shown increasing rates of BCS compared to mastectomy since 2010 (4% increase per year), with BCS comprising 51% of all breast cancer surgery [1].

Unfortunately, BCS can lead to significant breast deformity in up to 30% of patients which can create psychological burden, surgeon distrust, and dissatisfaction with cancer treatment [7, 8]. The goal of what has been termed "oncoplastic" breast reconstructive surgery is to surgically remove the breast cancer while at the same time rearranging or replacing tissue to preserve the breast's natural shape. Oncoplastic surgery is an accompaniment to BCS and has increased nationally by 241% from 2005 to 2016 [1]. However, the overall rate of oncoplastic breast surgery still remains low at 5% of those receiving BCS [1].

In the last decade, several advances in oncoplastic breast surgery have been made. Reconstructive options now include fat grafting, tissue rearrangement, and breast reduction techniques, as well as tissue replacement with local, regional, and free tissue transfer. Reconstruction is also now offered more commonly in the immediate setting, at the time of BCS, prior to radiation treatment. Oncoplastic surgery has been shown to improve patient satisfaction [9, 10] and cosmetic outcomes [11••] without an increased risk of complications [12, 13] or cancer recurrence [12, 14]. Here we review current surgical techniques for breast reconstruction following BCS, review the evidence for their safety and efficacy, and discuss our personal approach.

Fat Grafting

Initially following BCS, the surgical cavity fills with serous fluid, often leaving no observable deformity until months later when tissue retraction occurs following radiation. In this scenario, autologous fat grafting is one of a few options available to correct breast deformities. Fat can be harvested from multiple donor sites with standard suction assisted lipectomy techniques. Grafting then occurs using Coleman cannulas with multiple passes and small aliquots to fill the divot. Multiple rounds of fat grafting may be required to adequately correct the deformity, spaced approximately three months apart. On average 60–80% of the fat grafted volume will survive [15]. There are several techniques for fat harvest and processing, and limited research demonstrating superiority of any one technique [15–20].

Percutaneous fasciotomy or rigotomy is an adjunct procedure that can help release retracted scars and allow for an increased fat graft volume via needle [21], myringotomy blades [22], or the Coleman canula [23]. Rigotomy is performed by placing the scar under maximal tension and releasing with multiple stab incisions using the above instrument of choice. Following release, fat grafting is performed into the cavity until a small amount of lipoaspirate exits from the incisions. Ho Quoc et al. reviewed fat grafting and percutaneous fasciotomies in 1000 patients finding a 0.8% infection rate and minimal wound healing complications. They noted over-aggressive fasciotomy, however, can lead to overlying skin complications [21].

An additional benefit of fat grafting is improvement in skin quality following radiation, which is particularly intriguing in BCS patients since the majority receive adjuvant breast radiation. Studies have shown more than 90% of patients who undergo radiation therapy will have some form of skin reaction [24, 25]. Radiodermatitis has a spectrum of severity characterized by hyperpigmentation, erythema, dermal and subcutaneous thinning, along with scar contraction and loss of soft tissue envelope. These changes evolve over years following treatment [24]. In 2007, Rigotti et al. were the first to show fat grafting could improve skin quality in breast cancer patients with severe radiation damage. They attributed this improvement to the rejuvenating properties of the adipose-derived stem cells (ASCs) [26].

The most common complication resulting from fat grafting is palpable nodules from fat necrosis or oil cysts. Clinically detected rates of fat necrosis/oil cyst formation range from 2 to 18% [15, 27, 28]. Radiologically, there is a higher rate of detection of fat necrosis/oil cysts, with Juhl et al. showing 85% of patients developing oil cysts on mammography/ultrasound after fat grafting [29]. New calcifications can also be found following fat grafting in 5–20% of patients, in some circumstances necessitating further investigation [15, 29]. In a systematic review of all types of breast reconstruction, a higher rate of breast biopsy due to suspicious radiologic findings was found in those who had fat grafting compared to patients who did not (3.7% vs 1.6%) [15]. Ultrasound has been found to be reliable in differentiating benign from malignant lesions following fat grafting [30]. Infection rates following fat grafting are very low (0.7–1%) [15, 27], and major complications such as fat emboli and pneumothorax are extremely rare [15]. Donor site complications tend to be self-limiting and include ecchymosis, swelling, hematoma, and paresthesias. Visceral injury should be avoided with a thorough pre-operative exam including examination for hernias, as well as focus and precision intra-operatively. Finally, contour abnormalities are possible, especially when performing suction lipectomy over convex surfaces, but can typically be prevented with careful technique and selection of an appropriate donor site [31]. We prefer to avoid harvesting fat from the periumbilical region when possible in order to prevent injury to perforating vessels in case the patient requires flap reconstruction in the future.

When considering fat grafting in a patient with breast cancer history, oncologic safety is of utmost importance. Although fat grafting to the breast has become fairly ubiquitous, it was initially banned in 1987 due to concern for disrupting breast cancer imaging [32]. It was not until 2009, after multiple clinical studies helped quell this fear, that the American Society of Plastic Surgeons (ASPS) Task Force concluded that fat grafting to the breast could be performed, although data on long-term safety of the technique was lacking [33]. ASCs have been shown to activate and differentiate into adipocytes and endothelial cells, leading to graft survival [34]. This activating potential could theoretically support tumor progression and possibly metastasis as shown in multiple animal studies [35–38]. One study has shown an increase in local recurrence at 5 years after fat grafting in patients with in situ breast cancer (18% vs. 3%) [39]. However, larger studies have looked at patients with invasive breast cancer who had secondary fat grafting; compared to patients that did not have fat grafting, there were no significant differences in recurrence even when stratifying by invasive [40, 41] or in situ breast cancer [42, 43••]. Overall, the current literature supports that fat grafting in the breast cancer population does not increase recurrence rates [15, 44, 45••].

Lastly, fat grafting should be performed after margins have been proven negative, although there is not a consensus as to how long the waiting period should be. Some surgeons perform fat grafting immediately without obvious increase in recurrence rates; however, these studies lack control groups and adequate follow-up [46, 47]. In our practice we only offer fat grafting secondarily, at least three to 6 months after adjuvant radiation is completed.

Oncoplastic Tissue Rearrangement and Reduction

Despite fat grafting techniques, repair of BCS defects following radiation has been found to be more difficult with poor aesthetic outcomes and increased complication rates as high as 50–60% [9, 48]. Figure 1 shows an example of a relatively poor outcome following a delayed reconstruction of a post-BCS and radiation deformity. The benefits of oncoplastic tissue rearrangement and reduction surgery performed prior to radiation are the avoidance of these deformities and improved patient-reported quality of life [10]. Patient-reported satisfaction has been found to be highest in those who undergo immediate reconstruction of BCS defects compared to delayed reconstruction [9].

Oncoplastic surgery in most circumstances can occur at the time of BCS. Patients presenting with multiple foci of disease who are more likely to have positive margins should have a delayed immediate repair [48]. In this scenario, reconstruction can proceed 1–2 weeks following BCS when permanent pathological margins are confirmed to be negative. If a "delayed immediate" approach is undertaken, the plastic surgeon should plan the surgical incisions for the oncologic team in anticipation of the pattern to be used for reduction and/or rearrangement. We also recommend obtaining photos, measurements, and specimen weight. Patients in our practice are routinely offered a contralateral symmetry procedure at the time of the oncoplastic surgery if significant asymmetry will exist. Here we review approaches to immediate reconstruction with oncoplastic tissue rearrangement and reduction techniques.

Local Tissue Rearrangement and Augmentation Techniques

Ideal candidates for oncoplastic surgery are those with larger breasts (C-D cup), breast ptosis, asymmetry, and those requiring a sizeable tissue resection. Smaller breasted patients without significant ptosis may be candidates for tissue rearrangement and augmentation techniques. For smaller BCS defects in patients with properly positioned nipples, periareolar incisions can be used to completely separate the breast skin from the parenchyma, plicating the parenchyma where necessary following tumor resection to reshape the breast mound and redrape the skin [48].

Additional options for smaller breasted patients include the use of breast implants. With this technique, immediate reconstruction is performed by closing the BCS cavity with local tissue advancement, and a subpectoral breast augmentation is performed to reduce dead space and provide volume [49]. Largely this technique is avoided in our practice due to increased rates of capsular contracture which have been reported as high as 24% (grade II–IV) [49].

Auto-augmentation mastopexy techniques can be used to fill larger lumpectomy cavities in smaller but ptotic breasts. Dermoglandular breast flaps can be mobilized and transposed as an extension of the primary pedicle beyond the nipple areolar complex or a secondary pedicle independent of the primary nipple pedicle [50••]. In a series by Losken et al., the most common extended pedicle was the superomedial which was used to reconstruct lateral, superior, and medial defects [50••]. Common secondary pedicles are the inferior or inferolateral with a superior or superomedial primary nipple pedicle used for lateral

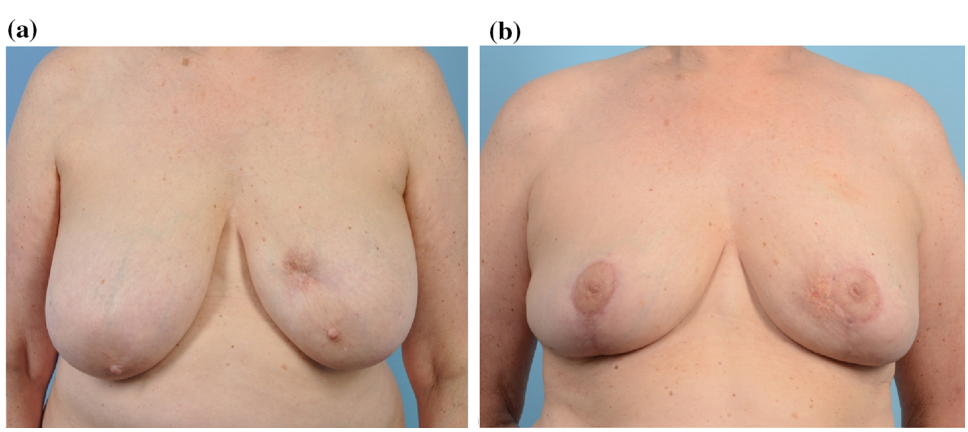

Fig. 1 **a** 5-year post-BCS and radiation breast deformity. **b** Bilateral breast reduction performed in delayed fashion

defects [50••]. Figure 2 shows a superiorly based dermoglandular breast flap transposed to successfully fill a large medial lumpectomy cavity.

Breast Mastopexy/Reduction Techniques

The majority of candidates for oncoplastic surgery will have a breast mastopexy/reduction technique. Reduction of the breast volume not only serves to maximize resection margins, but also may improve the efficiency of radiation treatments for larger breasted patients [51]. Vertical breast reduction patterns that base the nipple perfusion superomedial are great to address tumor locations in the lateral upper and lower poles of the breast. For patients with greater tissue excess or requiring significant skin resection, Wise pattern reductions with a variety of pedicle locations can be employed. Kronowitz et al. report a preference for the inferior pedicle technique with Wise pattern skin resection [52]. They report on several modifications of this technique dependent on tumor location, incorporating medial or lateral parenchyma to bolster the blood supply to the nipple [52]. Figure 3 shows an example of a superomedial pedicle Wise pattern reduction performed in an immediate fashion for a large lateral BCS cavity.

When a central tumor resection is required and the only remaining blood supply to the nipple will be the skin, reduction techniques may need to be combined with free nipple grafting or parenchymal reshaping without repositioning of the nipple areola complex [48]. In some circumstances the nipple areolar complex will need to be removed completely and reconstructed in a delayed fashion. Alternatively, an immediate nipple reconstruction can be considered. A single-stage technique for immediate nipple reconstruction has been described reconstructing the nipple on an inferior pedicle with a Wise pattern reduction [12].

Immediate postoperative complication rates after oncoplastic surgery are relatively low and include wound dehiscence 4.6%, nipple necrosis 0.9%, fat necrosis 4.3%, seroma 0.6%, and infection 2.8% [13]. When BCS and oncoplastic surgery is compared to total mastectomy with reconstruction, wound-related complications and surgical site infections have been documented to be significantly lower [53]. Oncoplastic surgery may also be a safer option for our obese population. In a series comparing oncoplastic reconstruction to immediate breast reconstruction following mastectomy, obese patients were ten times less likely to have a complication requiring reoperation and 20 times less likely to have a delay in adjuvant therapy in the oncoplastic group [54••].

The need for re-excision of positive margins following an oncoplastic procedure is always a concern and often necessitates completion mastectomy. In a series from MD Anderson Cancer Center, positive margins were found in only 5% of patients who had immediate oncoplastic rearrangement following BCS [55]. In a systematic review by Piper et al., the pooled re-excision rate was 3.5% with completion mastectomy in 3.7% of patients [13]. A meta-analysis of over 3000 patients found re-excision rates to be significantly lower in the oncoplastic group compared to BCS alone (4% compared to 14.6%) [11••]. These studies support the potential for improved surgical margins and safety with oncoplastic surgery. In our practice we ensure the tumor cavity has been adequately clipped following the oncoplastic surgery to not only guide postoperative radiotherapy but allow for re-identification of the surgical margins if necessary. Intraoperative frozen sections can be utilized to lower re-excision rates; however, this technique is not widely practiced due to inaccuracy [13].

Delay of adjuvant treatments and decreased sensitivity of postoperative surveillance following oncoplastic surgery is an additional concern that has been addressed in the literature. Oncoplastic surgery for those patients who require neoadjuvant chemotherapy has been shown to be safe without increased risk of complications or delay in adjuvant radiation therapy [56]. A long-term follow-up study evaluating postoperative surveillance for oncoplastic reduction patients found that the sensitivity of

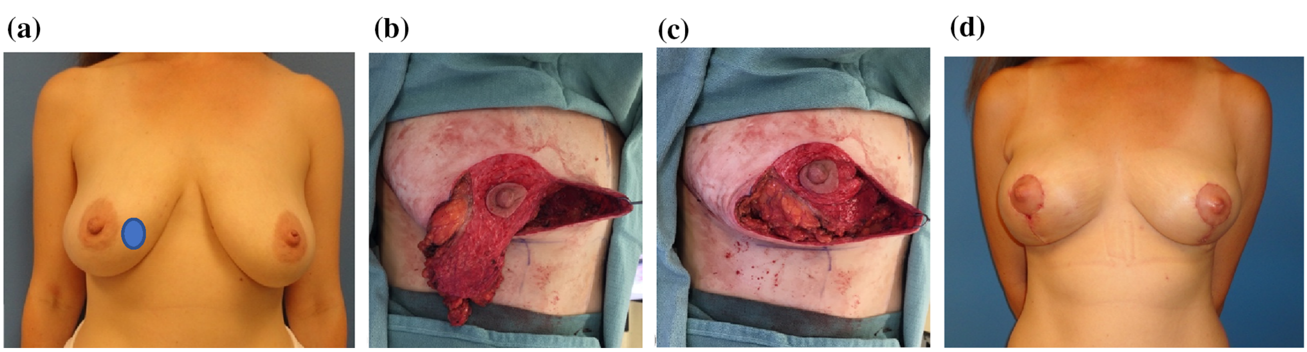

Fig. 2 **a** Preoperative photo demonstrating tumor location in the right breast. **b**, **c** Intraoperative photo demonstrating superiorly based dermoglandular flap, rotated into large medial BCS cavity. **d** Immediate postoperative result of mastopexy and tissue rearrangement

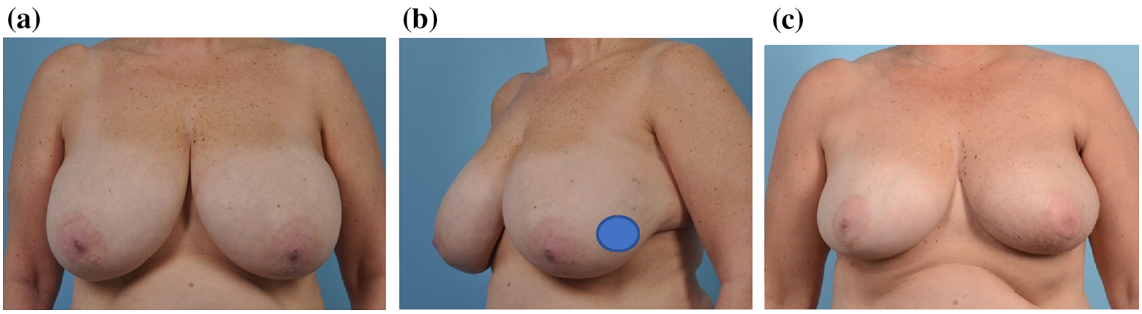

Fig. 3 **a**, **b** Preoperative photos breast with left lateral tumor. **c** 1-year post-radiation photo following immediate oncoplastic reduction with superomedial pedicle Wise pattern reduction and contralateral reduction for symmetry

mammograms was similar for those having oncoplastic reduction and BCS alone [57]. However, the oncoplastic reduction group had a trend toward longer time to mammographic stability with a potential increase in the amount of tissue sampling required [57]. Local–regional recurrence rates for oncoplastic procedures are reportedly low, 3.1% at two years in a systematic review of over 1000 cases [13].

Local, Regional, and Free Flap Reconstruction

Patients with small to medium sized breasts and/or larger defects and mild to moderate ptosis can also benefit from oncoplastic reconstruction after BCS. Rather than rearranging tissue and reducing the skin envelope, these patients are best reconstructed with the addition of local or distant tissue. These volume replacement techniques benefit patients who do not want or need a reduction and often prevent the need for contralateral symmetry surgery involving reduction or mastopexy. They also make BCS possible in patients who would traditionally need a mastectomy and reconstruction for a reasonable aesthetic outcome. A study by Smith et al. found patients treated with volume replacement had a lower body mass index (BMI, kg/m^2) compared to those treated with tissue rearrangement, mastopexy, and reduction techniques (24.1 versus 28.5, p = 0.0033). Only 8.3% of the 24 patients treated with tissue replacement underwent a contralateral procedure for symmetry, compared to 61.5% in the volume displacement group [58••]. Here we review reconstructive options with local, regional, and free tissue transfer.

Random Glandular Flaps

Random glandular and dermoglandular flaps have been described based from the axilla for superolateral defects [59] and the lateral breast and chest wall for superolateral and inferolateral defects [60–62]. These are technically less difficult to perform compared to the other flaps discussed, and also take less time. They are most useful in patients with medium to large breasts who do not desire a breast reduction and have small to moderate sized defects. A contralateral symmetry procedure may be more likely compared to the other flaps described below. Due to the lack of axial blood supply, there may also be an increased risk of fat necrosis when larger volumes of tissue are transposed.

Chest Wall Perforator Flaps

The lateral intercostal artery perforator (LICAP) flap and lateral thoracic artery perforator (LTAP) flap are useful for reconstruction of moderate sized lateral breast defects. The vessels for these flaps are a few centimeters anterior to the anterior latissimus border, in the 3^{rd}-8^{th} intercostal spaces [63, 64••]. Anterior intercostal artery perforator (AICAP) flaps are composed of tissue beneath the inframammary fold for reconstruction of central and lower medial defects [64••]. These perforators may originate from the internal mammary artery and may also be known as internal mammary artery perforator (IMAP) flaps in the literature [65, 66]. The ICAP adipofascial flaps can be folded over or used as propeller flaps, and a single perforator or multiple can be used [67]. Skin can also be included if needed. An example of a LICAP propeller flap is shown in Fig. 4.

Revision surgery may be needed in chest wall flaps that are designed as turnovers [66, 68]; however, dissection is more difficult and the risk of vascular compromise is greater in propeller flaps [69]. When performing propeller flaps without a skin paddle, the flap is de-epithelialized, and the dermis is examined to confirm normal perfusion during dissection of the vessels as well as flap inset. Range of motion of the arm is also performed prior to closure of the skin to ensure postoperative positioning restrictions are not needed. Benefits of chest wall perforator flaps include sparing muscle to avoid functional deficits, and also leaving the thoracodorsal vessels intact for the possibility of future reconstruction. These flaps have been shown to have no effect on surveillance imaging [70].

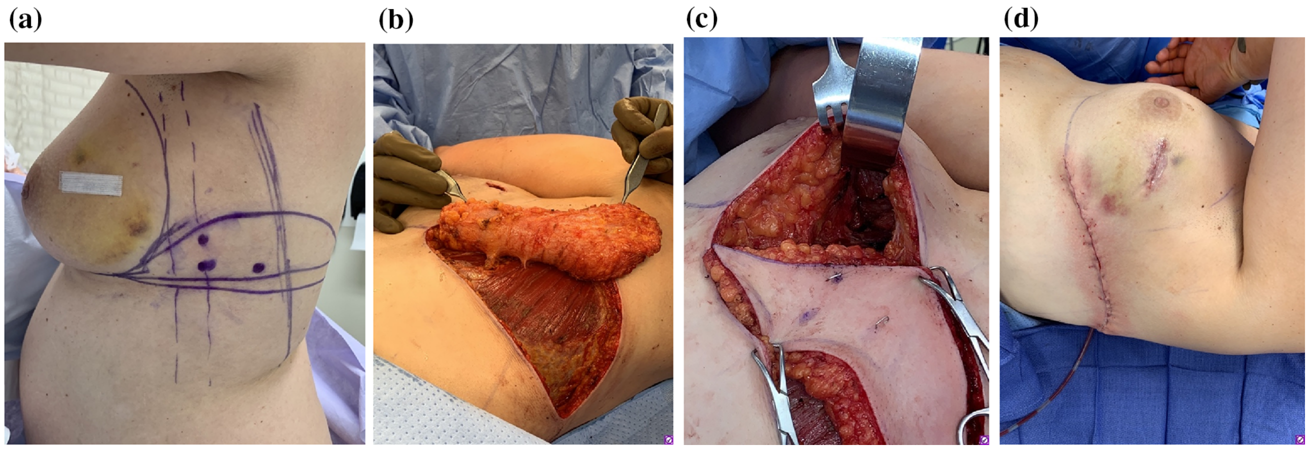

Fig. 4 **a** Patient with moderate sized lateral BCS defect, markings shown for LICAP. **b** LICAP and LTAP perforators identified and skeletonized. The LTAP perforator was clamped and sacrificed to allow for rotation as a propeller flap. **c** A tunnel to the moderate sized defect (specimen diameter 6 cm) was created after the flap was islanded. **d** Incision is within the braline

Flaps Based on Thoracodorsal Vessels: Latissimus and Thoracodorsal Artery Perforator Flaps

The latissimus dorsi flap may be used to reconstruct moderate to large sized BCS defects. Downsides of using muscle include donor site morbidity, as well as possible animation deformity, or atrophy if denervation is performed. The muscle has been shown to atrophy on average 8% in the first year even when the thoracodorsal nerve is left intact, with further, but less atrophy over the next two years compared to the contralateral side [71]. A descending branch latissimus dorsi "mini-flap" has been described using the incision for axillary node dissection, with no statistically significant difference in function compared to patients with local tissue rearrangement or no reconstruction after BCS [72].

The thoracodorsal artery perforator (TDAP) flap also spares the muscle to reduce donor site morbidity. In one randomized study comparing the latissimus flap and TDAP flap for partial breast reconstruction, there was no statistically significant difference in operative time or complication rates including flap loss [73]. The patients reconstructed with TDAP flaps had less shoulder disability at 3, 6, and 12 months after surgery. However, patients who had partial breast reconstruction with latissimus flaps have been shown to have high satisfaction using the BREAST-Q module, including physical well-being (average score 87) [74]. The traditional latissimus flap may therefore still be reasonable for larger defects (> 150 grams). Benefits of these flaps include relative technical ease in the case of a muscle flap, flexibility to replace a moderate amount of skin and volume if needed, and longer pedicles. These flaps are most easily placed in lateral defects, however can often reach the medial breast. Disadvantages include some decrease in shoulder function when harvesting muscle, as well as not having the latissimus available for reconstruction if the patient has recurrent cancer.

Omental Flap

Omental flaps have been described for partial breast reconstruction. Minimal donor site morbidity is achieved with laparoscopic harvest, and pedicled or free flap techniques may be used [75]. Unlike most chest wall perforator flaps, the omentum can be used to reach the medial chest even when pedicled. A complication rate of 12% has been described, including partial or total flap loss and ventral hernia, and 5.8% developed nodules or induration, possibly fat necrosis [76]. Furthermore, omental flap volume is unpredictable and at times inadequate, with insufficient volume in some patients when resection size exceeds 200 grams [76]. Oncologic safety despite the presence of stem cells within the omentum is presumed but not conclusively proven [76]. For these reasons, as well as the need for comfort with laparoscopic surgery techniques or an additional surgeon who is, we do not currently perform these flaps for breast reconstruction at our institution.

Free Flaps

Free flaps may be most useful for reconstructing large medial or superior breast defects, or in patients requiring significant skin replacement, particularly in the delayed setting [58••, 77]. Donor sites for partial breast free flap reconstruction include mini superficial and deep inferior epigastric artery flaps [77], as well as thigh-based flaps including gracilis and profunda artery perforator flaps [58••]. Revision rates may be similar to pedicled flaps, reported in one study as 27% [58••]. Recipient vessels commonly include the internal mammary, thoracoacromial, and thoracodorsal arteries and veins. Completion mastectomy and reconstruction should also be considered in these patients.

Thoughtful flap selection for patients having partial breast reconstruction with volume replacement is key. This is typically based on the size and location of the defect, as well as available donor sites. Small to medium sized defects of the lateral and inferior or central breast may be reconstructed with random glandular or perforator flaps based on the intercostal or lateral thoracic vessels. Larger defects may be better filled with TDAP or latissimus dorsi flaps [78]. Free flaps are reserved for large superior or medial defects. The omentum may also have a role in partial breast reconstruction. Finally, mastopexy techniques may be combined with volume replacement techniques in patients with small to moderate sized, but ptotic breasts for best results [79].

Conclusions

For patients choosing breast conservation surgery several surgical options for reconstruction exist. Fat grafting offers a safe but, in our opinion, less effective option for delayed reconstruction of sizable defects [15, 27, 40–45••]. The benefits of oncoplastic breast surgery performed prior to radiation are avoidance of breast deformity and improved patient-reported quality of life and satisfaction [10]. The majority of candidates for oncoplastic surgery in our practice are offered a breast mastopexy/reduction technique with a contralateral procedure for symmetry. Oncoplastic reduction techniques maximize tumor resection margins while also improving the efficiency of radiation treatments [51]. Volume replacement techniques with local, regional, and free tissue transfer benefit patients who do not need or want a breast reduction and often prevent the need for contralateral symmetry procedures [58••].

In our practice, we follow patients for at least 1 year to assess postoperative outcomes. We find that very few patients require reoperation for asymmetry or poor aesthetic results. Advantages of oncoplastic surgery include decreased complication rates when compared to mastectomy with breast reconstruction especially for our growing obese population [13, 53, 54••]. Oncoplastic surgery has not been found to delay adjuvant treatments or decrease sensitivity of postoperative surveillance [56, 57, 70]. Additionally, re-excision of positive margins is reportedly low at 3.5–5% supporting the potential for improved surgical margins and safety [11••, 13, 55]. Importantly, oncoplastic surgery has not been found to increase the risk of cancer recurrence [11••, 13, 14, 80, 81]. Finally, oncoplastic reconstruction offers many patients an option for breast conservation with reasonable aesthetic outcomes, including those with large tumors or even multifocal disease, which traditionally would be treated with mastectomy [82].

Based on current evidence we strongly recommend that all patients considering breast conservation surgery should be offered a consultation with a plastic surgeon to review their reconstructive options. Continued advancement in surgical techniques will likely expand future options to optimize patient safety, outcomes, and satisfaction.

Funding No funding was received.

Compliance with Ethical Guidelines

Conflict of interest Karri Adamson, David Rivedal and Erin Doren declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Recently published papers of particular interest have been highlighted as:
•• Of major importance

1. Jonczyk MM, Jean J, Graham R, Chatterjee A. Surgical trends in breast cancer: a rise in novel operative treatment options over a 12 year analysis. Breast Cancer Res Treat. 2019;173(2):267–74. https://doi.org/10.1007/s10549-018-5018-1.
2. Fisher B, Anderson S, Bryant J, Margolese RG, Deutsch M, Fisher ER, et al. Twenty-year follow-up of a randomized trial comparing total mastectomy, lumpectomy, and lumpectomy plus irradiation for the treatment of invasive breast cancer. N Engl J Med. 2002;347(16):1233–41. https://doi.org/10.1056/NEJMoa022152.
3. Veronesi U, Cascinelli N, Mariani L, Greco M, Saccozzi R, Luini A, et al. Twenty-year follow-up of a randomized study comparing breast-conserving surgery with radical mastectomy for early breast cancer. N Engl J Med. 2002;347(16):1227–32. https://doi.org/10.1056/NEJMoa020989.
4. Agarwal S, Pappas L, Neumayer L, Kokeny K, Agarwal J. Effect of breast conservation therapy vs mastectomy on disease-specific survival for early-stage breast cancer. JAMA Surg. 2014;149(3):267–74. https://doi.org/10.1001/jamasurg.2013.3049.
5. Hwang ES, Lichtensztajn DY, Gomez SL, Fowble B, Clarke CA. Survival after lumpectomy and mastectomy for early stage invasive breast cancer: the effect of age and hormone receptor status. Cancer. 2013;119(7):1402–11. https://doi.org/10.1002/cncr.27795.
6. Tan MP. Is there an ideal breast conservation rate for the treatment of breast cancer? Ann Surg Oncol. 2016;23(9):2825–31. https://doi.org/10.1245/s10434-016-5267-3.
7. Waljee JF, Hu ES, Newman LA, Alderman AK. Correlates of patient satisfaction and provider trust after breast-conserving surgery. Cancer. 2008;112(8):1679–87. https://doi.org/10.1002/cncr.23351.

8. Clough KB, Cuminet J, Fitoussi A, Nos C, Mosseri V. Cosmetic sequelae after conservative treatment for breast cancer: classification and results of surgical correction. Ann Plast Surg. 1998;41(5):471–81. https://doi.org/10.1097/00000637-199811000-00004.
9. Egro FM, Pinell-White X, Hart AM, Losken A. The use of reduction mammaplasty with breast conservation therapy: an analysis of timing and outcomes. Plast Reconstr Surg. 2015;135(6):963e–71e. https://doi.org/10.1097/prs.0000000000001274.
10. Veiga DF, Veiga-Filho J, Ribeiro LM, Archangelo I Jr, Balbino PF, Caetano LV, et al. Quality-of-life and self-esteem outcomes after oncoplastic breast-conserving surgery. Plast Reconstr Surg. 2010;125(3):811–7. https://doi.org/10.1097/PRS.0b013e3181ccdac5.
11. •• Losken A, Dugal CS, Styblo TM, Carlson GW. A meta-analysis comparing breast conservation therapy alone to the oncoplastic technique. Ann Plast Surg. 2014;72(2):145–9. https://doi.org/10.1097/sap.0b013e3182605598. *A meta-analysis comparing outcomes for patients with BCS alone compared with oncoplastic reconstruction. The study includes 3165 patients in the BCS oncoplastic surgery group and 5494 in the BCS alone group. They find the positive margin rate to be significantly lower in the oncoplastic group also with lower re-excision rates.*
12. Crown A, Rocha FG, Grumley JW. Oncoplastic central partial mastectomy and neoareolar reduction mammoplasty with immediate nipple reconstruction: an initial report of a novel option for breast conservation in patients with subareolar tumors. Ann Surg Oncol. 2019;26(13):4284–93. https://doi.org/10.1245/s10434-019-07731-y.
13. Piper ML, Esserman LJ, Sbitany H, Peled AW. Outcomes following oncoplastic reduction mammoplasty: a systematic review. Ann Plast Surg. 2016;76(Suppl 3):S222–6. https://doi.org/10.1097/sap.0000000000000720.
14. Chen JY, Huang YJ, Zhang LL, Yang CQ, Wang K. Comparison of oncoplastic breast-conserving surgery and breast-conserving surgery alone: a meta-analysis. J Breast Cancer. 2018;21(3):321–9. https://doi.org/10.4048/jbc.2018.21.e36.
15. Groen JW, Negenborn VL, Twisk D, Rizopoulos D, Ket JCF, Smit JM, et al. Autologous fat grafting in onco-plastic breast reconstruction: a systematic review on oncological and radiological safety, complications, volume retention and patient/surgeon satisfaction. J Plast Reconstr Aesthet Surg. 2016;69(6):742–64. https://doi.org/10.1016/j.bjps.2016.03.019.
16. Agostini T, Lazzeri D, Pini A, Marino G, Li Quattrini A, Bani D, et al. Wet and dry techniques for structural fat graft harvesting: histomorphometric and cell viability assessments of lipoaspirated samples. Plast Reconstr Surg. 2012;130(2):331e–9e. https://doi.org/10.1097/PRS.0b013e3182589f76.
17. Li K, Gao J, Zhang Z, Li J, Cha P, Liao Y, et al. Selection of donor site for fat grafting and cell isolation. Aesthet Plast Surg. 2013;37(1):153–8. https://doi.org/10.1007/s00266-012-9991-1.
18. Nava MB, Blondeel P, Botti G, Casabona F, Catanuto G, Clemens MW, et al. International expert panel consensus on fat grafting of the breast. Plast Reconstr Surg Glob Open. 2019;7(10):e2426. https://doi.org/10.1097/gox.0000000000002426.
19. Small K, Choi M, Petruolo O, Lee C, Karp N. Is there an ideal donor site of fat for secondary breast reconstruction? Aesthet Surg J. 2014;34(4):545–50. https://doi.org/10.1177/1090820x14526751.
20. Smith P, Adams WP Jr, Lipschitz AH, Chau B, Sorokin E, Rohrich RJ, et al. Autologous human fat grafting: effect of harvesting and preparation techniques on adipocyte graft survival. Plast Reconstr Surg. 2006;117(6):1836–44. https://doi.org/10.1097/01.prs.0000218825.77014.78.
21. Ho Quoc C, Sinna R, Gourari A, La Marca S, Toussoun G, Delay E. Percutaneous fasciotomies and fat grafting: indications for breast surgery. Aesthet Surg J. 2013;33(7):995–1001. https://doi.org/10.1177/1090820x13501511.
22. Mathur B, Loh CYY. Rigotomy using myringotomy blades prior to lipofilling. Aesthet Plast Surg. 2019;43(3):874–5. https://doi.org/10.1007/s00266-019-01354-0.
23. El Khoury J, Adams D, Saliba C, El Rayes J, Massin A, Fenoll C. Surgical approach to a post-traumatic fat fracture. Cureus. 2018;10(9):e3378. https://doi.org/10.7759/cureus.3378.
24. Borrelli MR, Patel RA, Sokol J, Nguyen D, Momeni A, Longaker MT, et al. Fat chance: the rejuvenation of irradiated skin. Plast Reconstr Surg Glob Open. 2019;7(2):e2092. https://doi.org/10.1097/gox.0000000000002092.
25. Borrelli MR, Shen AH, Lee GK, Momeni A, Longaker MT, Wan DC. Radiation-induced skin fibrosis: pathogenesis, current treatment options, and emerging therapeutics. Ann Plast Surg. 2019;83(4S Suppl 1):S59–S64. https://doi.org/10.1097/sap.0000000000002098.
26. Rigotti G, Marchi A, Galie M, Baroni G, Benati D, Krampera M, et al. Clinical treatment of radiotherapy tissue damage by lipoaspirate transplant: a healing process mediated by adipose-derived adult stem cells. Plast Reconstr Surg. 2007;119(5):1409–22. https://doi.org/10.1097/01.prs.0000256047.47909.71 **discussion 23-4**.
27. De Decker M, De Schrijver L, Thiessen F, Tondu T, Van Goethem M, Tjalma WA. Breast cancer and fat grafting: efficacy, safety and complications-a systematic review. Eur J Obstet Gynecol Reprod Biol. 2016;207:100–8. https://doi.org/10.1016/j.ejogrb.2016.10.032.
28. Doren EL, Parikh RP, Laronga C, Hiro ME, Sun W, Lee MC, et al. Sequelae of fat grafting postmastectomy: an algorithm for management of fat necrosis. Eplasty. 2012;12:e53.
29. Juhl AA, Redsted S, Engberg Damsgaard T. Autologous fat grafting after breast conserving surgery: breast imaging changes and patient-reported outcome. J Plast Reconstr Aesthet Surg. 2018;71(11):1570–6. https://doi.org/10.1016/j.bjps.2018.08.012.
30. Parikh RP, Doren EL, Mooney B, Sun WV, Laronga C, Smith PD. Differentiating fat necrosis from recurrent malignancy in fat-grafted breasts: an imaging classification system to guide management. Plast Reconstr Surg. 2012;130(4):761–72. https://doi.org/10.1097/PRS.0b013e318262f03b.
31. Simonacci F, Bertozzi N, Grieco MP, Grignaffini E, Raposio E. Procedure, applications, and outcomes of autologous fat grafting. Ann Med Surg. 2017;20:49–60. https://doi.org/10.1016/j.amsu.2017.06.059.
32. Report on Autologous Fat Transplantation. ASPRS Ad-Hoc Committee on new procedures, September 30, 1987. Plast Surg Nurs. 1987;7(4):140–1.
33. Gutowski KA. Current applications and safety of autologous fat grafts: a report of the ASPS fat graft task force. Plast Reconstr Surg. 2009;124(1):272–80. https://doi.org/10.1097/PRS.0b013e3181a09506.
34. Hong KY, Yim S, Kim HJ, Jin US, Lim S, Eo S, et al. The fate of the adipose-derived stromal cells during angiogenesis and adipogenesis after cell-assisted lipotransfer. Plast Reconstr Surg. 2018;141(2):365–75. https://doi.org/10.1097/prs.0000000000004021.
35. Lyes MA, Payne S, Ferrell P, Pizzo SV, Hollenbeck ST, Bachelder RE. Adipose stem cell crosstalk with chemo-residual breast cancer cells: implications for tumor recurrence. Breast Cancer Res Treat. 2019;174(2):413–22. https://doi.org/10.1007/s10549-018-05103-w.
36. Orbay H, Hinchcliff KM, Charvet HJ, Sahar DE. Fat graft safety after oncologic surgery: addressing the contradiction between in vitro and clinical studies. Plast Reconstr Surg.

2018;142(6):1489–99. https://doi.org/10.1097/prs.0000000000004992.
37. Rowan BG, Gimble JM, Sheng M, Anbalagan M, Jones RK, Frazier TP, et al. Human adipose tissue-derived stromal/stem cells promote migration and early metastasis of triple negative breast cancer xenografts. PLoS ONE. 2014;9(2):e89595. https://doi.org/10.1371/journal.pone.0089595.
38. Xu H, Li W, Luo S, Yuan J, Hao L. Adipose derived stem cells promote tumor metastasis in breast cancer cells by stem cell factor inhibition of miR20b. Cell Signal. 2019;62:109350. https://doi.org/10.1016/j.cellsig.2019.109350.
39. Petit JY, Rietjens M, Botteri E, Rotmensz N, Bertolini F, Curigliano G, et al. Evaluation of fat grafting safety in patients with intraepithelial neoplasia: a matched-cohort study. Ann Oncol. 2013;24(6):1479–84. https://doi.org/10.1093/annonc/mds660.
40. Kaoutzanis C, Xin M, Ballard TN, Welch KB, Momoh AO, Kozlow JH, et al. Autologous fat grafting after breast reconstruction in postmastectomy patients: complications, biopsy rates, and locoregional cancer recurrence rates. Ann Plast Surg. 2016;76(3):270–5. https://doi.org/10.1097/sap.0000000000000561.
41. Vyas KS, DeCoster RC, Burns JC, Rodgers LT, Shrout MA, Mercer JP, et al. Autologous fat grafting does not increase risk of oncologic recurrence in the reconstructed breast. Ann Plast Surg. 2020. https://doi.org/10.1097/sap.0000000000002285.
42. Mestak O, Hromadkova V, Fajfrova M, Molitor M, Mestak J. Evaluation of oncological safety of fat grafting after breast-conserving therapy: a prospective study. Ann Surg Oncol. 2016;23(3):776–81. https://doi.org/10.1245/s10434-015-4908-2.
43. •• Petit JY, Maisonneuve P, Rotmensz N, Bertolini F, Rietjens M. Fat grafting after invasive breast cancer: a matched case-control study. Plast Reconstr Surg. 2017;139(6):1292–6. https://doi.org/10.1097/prs.0000000000003339. *This large case-control study compared fat grafting to the breast after breast conserving surgery compared to patients that did not have fat grafting. There was no difference in local or distant recurrence rates.*
44. Cohen S, Sekigami Y, Schwartz T, Losken A, Margenthaler J, Chatterjee A. Lipofilling after breast conserving surgery: a comprehensive literature review investigating its oncologic safety. Gland Surg. 2019;8(5):569–80. https://doi.org/10.21037/gs.2019.09.09.
45. •• Wang K, Dai Y, Pan Y, Cheng P, Jin X. Local-regional recurrence risk after autologous fat grafting in breast cancer patients: A systematic review and meta-analysis. J Surg Oncol. 2020;121(3):435–40. https://doi.org/10.1002/jso.25829. *This recent meta-analysis and systematic review of investigated local-regional recurrences in patients that had fat grafting to the breast. They did not show any increased recurrence based on oncologic surgery type, invasive or* in situ *breast cancer.*
46. Khan LR, Raine CR, Dixon JM. Immediate lipofilling in breast conserving surgery. Eur J Surg Oncol. 2017;43(8):1402–8. https://doi.org/10.1016/j.ejso.2017.03.014.
47. Molto Garcia R, Gonzalez Alonso V, Villaverde Domenech ME. Fat grafting in immediate breast reconstruction. Avoiding breast sequelae. Breast Cancer. 2016;23(1):134–40. https://doi.org/10.1007/s12282-014-0541-3.
48. Kronowitz SJ, Kuerer HM, Buchholz TA, Valero V, Hunt KK. A management algorithm and practical oncoplastic surgical techniques for repairing partial mastectomy defects. Plast Reconstr Surg. 2008;122(6):1631–47. https://doi.org/10.1097/PRS.0b013e31818cbf1b.
49. Barnea Y, Friedman O, Arad E, Barsuk D, Menes T, Zaretski A, et al. An oncoplastic breast augmentation technique for immediate partial breast reconstruction following breast conservation. Plast Reconstr Surg. 2017;139(2):348e–57e. https://doi.org/10.1097/prs.0000000000003005.
50. •• Losken A, Hart AM, Dutton JW, Broecker JS, Styblo TM, Carlson GW. The expanded use of autoaugmentation techniques in oncoplastic breast surgery. Plast Reconstr Surg. 2018;141(1):10–9. https://doi.org/10.1097/prs.0000000000004009. *This study describes the use of autoaugmentation techniques in oncoplastic reduction and compares outcomes with traditional oncoplastic reduction in 333 patients. They find autoaugmentation techniques to be safe and effective without increased complications rates in comparison to standard technique.*
51. Hernanz F, Regano S, Vega A, Gomez Fleitas M. Reduction mammaplasty: an advantageous option for breast conserving surgery in large-breasted patients. Surg Oncol. 2010;19(4):e95–102. https://doi.org/10.1016/j.suronc.2009.08.001.
52. Kronowitz SJ, Hunt KK, Kuerer HM, Strom EA, Buchholz TA, Ensor JE, et al. Practical guidelines for repair of partial mastectomy defects using the breast reduction technique in patients undergoing breast conservation therapy. Plast Reconstr Surg. 2007;120(7):1755–68. https://doi.org/10.1097/01.prs.0000287130.77835.f6.
53. Carter SA, Lyons GR, Kuerer HM, Bassett RL Jr, Oates S, Thompson A, et al. Operative and oncologic outcomes in 9861 patients with operable breast cancer: single-institution analysis of breast conservation with oncoplastic reconstruction. Ann Surg Oncol. 2016;23(10):3190–8. https://doi.org/10.1245/s10434-016-5407-9.
54. •• Tong WM, Baumann DP, Villa MT, Mittendorf EA, Liu J, Robb GL, et al. Obese women experience fewer complications after oncoplastic breast repair following partial mastectomy than after immediate total breast reconstruction. Plast Reconstr Surg. 2016;137(3):777–91. https://doi.org/10.1097/01.prs.0000479939.69211.19. *This study compares outcomes for 408 obese patients (BMI > 30) with oncoplastic breast reconstruction versus immediate breast reconstruction. They find that the oncoplastic reconstruction group, despite being older, more obese, and having more comorbidities, had fewer major complications comparatively.*
55. Kronowitz SJ, Feledy JA, Hunt KK, Kuerer HM, Youssef A, Koutz CA, et al. Determining the optimal approach to breast reconstruction after partial mastectomy. Plast Reconstr Surg. 2006;117(1):1–11. https://doi.org/10.1097/01.prs.0000194899.01875.d6 **discussion 2-4**.
56. Adamson K, Chavez-MacGregor M, Caudle A, Smith B, Baumann D, Liu J, et al. Neoadjuvant chemotherapy does not increase complications in oncoplastic breast-conserving surgery. Ann Surg Oncol. 2019;26(9):2730–7. https://doi.org/10.1245/s10434-019-07408-6.
57. Losken A, Schaefer TG, Newell M, Styblo TM. The impact of partial breast reconstruction using reduction techniques on postoperative cancer surveillance. Plast Reconstr Surg. 2009;124(1):9–17. https://doi.org/10.1097/PRS.0b013e3181ab10e5.
58. •• Smith ML, Molina BJ, Dayan E, Jablonka EM, Okwali M, Kim JN, et al. Defining the role of free flaps in partial breast reconstruction. J Reconstr Microsurg. 2018;34(3):185–92. https://doi.org/10.1055/s-0037-1607363. *This article explores differences in patients with BCS who underwent volume displacement compared to volume replacement reconstruction, with a focus on defects reconstructed with free flaps.*
59. Bordoni D, Cadenelli P, Ornelli M, Falco G, Accurso A, Gloria A, et al. The axillary flap in oncoplastic resection of breast cancers located in the upper-outer quadrants: a new surgical technique. BMC Surg. 2019;18(Suppl 1):21. https://doi.org/10.1186/s12893-018-0467-3.

60. Hong S, Wang S, Liu J, Qiang Z, Zheng X, Chen G. Usefulness of lateral thoracic adipofascial flaps after breast-conserving surgery in small-to moderate-sized breasts. Clin Breast Cancer. 2019;19(5):370–6. https://doi.org/10.1016/j.clbc.2019.04.009.
61. Nakagomi H, Inoue M, Nakada H, Ohmori M, Nakayama Y, Furuya K, et al. Lateral thoracoaxillar dermal-fat flap for breast conserving surgery: the changes of the indication and long-term results. Breast Cancer. 2019;26(5):595–601. https://doi.org/10.1007/s12282-019-00959-2.
62. Singh G, Kohli PS, Bagaria D. Lateral oncoplastic breast surgery (LOBS)—a new surgical technique and short term results. Am J Surg. 2018;216(6):1166–70. https://doi.org/10.1016/j.amjsurg.2017.09.016.
63. Hamdi M, Spano A, Van Landuyt K, D'Herde K, Blondeel P, Monstrey S. The lateral intercostal artery perforators: anatomical study and clinical application in breast surgery. Plast Reconstr Surg. 2008;121(2):389–96. https://doi.org/10.1097/01.prs.0000298317.65296.cf.
64. •• Soumian S, Parmeshwar R, Chandarana M, Marla S, Narayanan S, Shetty G. Chest wall perforator flaps for partial breast reconstruction: Surgical outcomes from a multicenter study. Arch Plast Surg. 2020;47(2):153–9. https://doi.org/10.5999/aps.2019.01186. *This article reviews techniques and results of intercostal artery perforator and lateral thoracic artery perforator flaps in the oncoplastic setting.*
65. Hamdi M, Van Landuyt K, de Frene B, Roche N, Blondeel P, Monstrey S. The versatility of the inter-costal artery perforator (ICAP) flaps. J Plast Reconstr Aesthet Surg. 2006;59(6):644–52. https://doi.org/10.1016/j.bjps.2006.01.006.
66. Huizum MAV, Hage JJ, Oldenburg HA, Hoornweg MJ. Internal mammary artery perforator flap for immediate volume replacement following wide local excision of breast cancer. Arch Plast Surg. 2017;44(6):502–8. https://doi.org/10.5999/aps.2016.00458.
67. McCulley SJ, Schaverien MV, Tan VK, Macmillan RD. Lateral thoracic artery perforator (LTAP) flap in partial breast reconstruction. J Plast Reconstr Aesthet Surg. 2015;68(5):686–91. https://doi.org/10.1016/j.bjps.2015.01.008.
68. Hakakian CS, Lockhart RA, Kulber DA, Aronowitz JA. Lateral intercostal artery perforator flap in breast reconstruction: a simplified pedicle permits an expanded role. Ann Plast Surg. 2016;76(Suppl 3):S184–90. https://doi.org/10.1097/sap.0000000000000752.
69. Kim JB, Eom JR, Lee JW, Lee J, Park HY, Yang JD. Utility of two surgical techniques using a lateral intercostal artery perforator flap after breast-conserving surgery: a single-center retrospective study. Plast Reconstr Surg. 2019;143(3):477e–87e. https://doi.org/10.1097/prs.0000000000005374.
70. Hu J, Cuffolo G, Parulekar V, Chan V, Tenovici A, Roy PG. The results of surveillance imaging after breast conservation surgery and partial breast reconstruction with chest wall perforator flaps; a qualitative analysis compared with standard breast-conserving surgery for breast cancer. Clin Breast Cancer. 2019;19(3):e422–7. https://doi.org/10.1016/j.clbc.2019.01.010.
71. Kang CM, Shim JS. Volume change of pedicled latissimus dorsi muscle flap after partial breast reconstruction. J Reconstr Microsurg. 2018;34(8):651–7. https://doi.org/10.1055/s-0038-1667176.
72. Zhou L, Wang Y, Cai R, Huang J, Li X, Xie Z, et al. Pedicled descending branch latissimus dorsi mini-flap in repairing partial mastectomy defect: shoulder functional and esthetic outcomes. J Surg Oncol. 2019;120(3):518–26. https://doi.org/10.1002/jso.25524.
73. Abdelrahman EM, Nawar AM, Balbaa MA, Shoulah AA, Shora AA, Kharoub MS. Oncoplastic volume replacement for breast cancer: latissimus dorsi flap versus thoracodorsal artery perforator flap. Plast Reconstr Surg Glob Open. 2019;7(10):e2476. https://doi.org/10.1097/gox.0000000000002476.
74. Mericli AF, Szpalski C, Schaverien MV, Selber JC, Adelman DM, Garvey PB, et al. The latissimus dorsi myocutaneous flap is a safe and effective method of partial breast reconstruction in the setting of breast-conserving therapy. Plast Reconstr Surg. 2019;143(5):927e–35e. https://doi.org/10.1097/prs.0000000000005577.
75. Ni C, Zhu Z, Xin Y, Xie Q, Yuan H, Zhong M, et al. Oncoplastic breast reconstruction with omental flap: a retrospective study and systematic review. J Cancer. 2018;9(10):1782–90. https://doi.org/10.7150/jca.25556.
76. Zaha H, Abe N, Sagawa N, Unesoko M. Oncoplastic surgery with omental flap reconstruction: a study of 200 cases. Breast Cancer Res Treat. 2017;162(2):267–74. https://doi.org/10.1007/s10549-017-4124-9.
77. Spiegel AJ, Eldor L. Partial breast reconstruction with mini superficial inferior epigastric artery and mini deep inferior epigastric perforator flaps. Ann Plast Surg. 2010;65(2):147–54. https://doi.org/10.1097/SAP.0b013e3181c9dcb2.
78. Lee JW, Kim MC, Park HY, Yang JD. Oncoplastic volume replacement techniques according to the excised volume and tumor location in small- to moderate-sized breasts. Gland Surg. 2014;3(1):14–21. https://doi.org/10.3978/j.issn.2227-684X.2014.02.02.
79. Schwartz JD. New approach to oncoplastic breast conservation: combining autologous volume replacement and the wise-pattern mammaplasty. Plast Reconstr Surg Glob Open. 2018;6(10):e1987. https://doi.org/10.1097/gox.0000000000001987.
80. De La Cruz L, Blankenship SA, Chatterjee A, Geha R, Nocera N, Czerniecki BJ, et al. Outcomes after oncoplastic breast-conserving surgery in breast cancer patients: a systematic literature review. Ann Surg Oncol. 2016;23(10):3247–58. https://doi.org/10.1245/s10434-016-5313-1.
81. Gulcelik MA, Dogan L, Yuksel M, Camlibel M, Ozaslan C, Reis E. Comparison of outcomes of standard and oncoplastic breast-conserving surgery. J Breast Cancer. 2013;16(2):193–7. https://doi.org/10.4048/jbc.2013.16.2.193.
82. Crown A, Laskin R, Rocha FG, Grumley J. Extreme oncoplasty: expanding indications for breast conservation. Am J Surg. 2019;217(5):851–6. https://doi.org/10.1016/j.amjsurg.2019.01.004.