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Multimodality imaging of the Reconstructed Breast

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Abstract

OBJECTIVE—The purpose of this article is to illustrate the imaging characteristics and pathologic findings associated with various types of breast reconstruction in women who have undergone mastectomy to treat breast cancer.

CONCLUSION—As the use of breast reconstruction becomes more prevalent, it is imperative that radiologists interpreting imaging studies identify spectrum of normal and abnormal imaging findings associated with differing breast reconstruction techniques, recognize imaging manifestation of expected complications and reliably distinguish these from malignancy.

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Introduction

One in eight women in the United States will develop breast cancer. In 2013, an estimated 232,340 new cases of invasive breast carcinoma were diagnosed along with 6,640 cases of breast carcinoma in situ (DCIS). Twenty to forty percent of patients with breast cancer will undergo breast reconstruction [1]. Currently, the most frequent reconstruction techniques include the use of autologous tissue or implants, or a combination of both. Several factors influence the type of reconstruction chosen, including the patient's desires, body habitus, medical condition, and the need for adjuvant therapy.

The radiologist should be knowledgeable about the anatomy of the reconstructed breast and about the common and uncommon imaging findings in breasts reconstructed with implants or with autologous flaps from the abdomen or latissimus dorsi (LD) myocutaneous flaps. Benign findings often seen in the reconstructed breast, including hematomas, infections, epidermal inclusion cysts, and fat necrosis, should be distinguished from malignant findings, such as recurrent primary tumors and sarcomas.

In this review, we illustrate the expected and unexpected imaging and pathologic findings associated with breast reconstruction with autologous tissue flaps and implants in women who have undergone mastectomy to treat breast cancer.

Reconstruction with Autologous Tissue Flaps

An autologous myocutaneous flap reconstruction rebuilds a breast mound using tissue from another part of the body, comprising skin, subcutaneous fat, and muscle. The advantages of this type of reconstruction include a better aesthetic appearance with better suppleness and a more natural-appearing disposition of the breast compared to an implant [2].

The use of autologous tissue flaps has evolved since the LD flap was introduced in 1906 and the transverse rectus abdominis myocutaneous (TRAM) flap's introduction in 1982 [3, 4]. The abdominal wall has become a popular option as a donor site for autologous breast reconstruction. TRAM flap techniques have been modified over time to decrease the morbidity associated with breast reconstruction, and several TRAM variants are available [5], including the pedicled TRAM flap (Fig. 1A) and the free deep inferior epigastric perforator (DIEP) flap (Fig. 1B). The vessels that nourish the abdominal wall can be ligated or kept intact in a TRAM flap reconstruction (Fig. 2).

The pedicled TRAM flap technique transfers the rectus abdominis muscle through a tunnel under the skin to the mastectomy site with its proximal attachments (the superior epigastric vessels) intact, thereby preserving its superior blood supply. This is a shorter and easier procedure than a free TRAM flap reconstruction, without the need for microvascular techniques, but it has a limited blood supply, limiting the size of the flap to the hemi-abdomen [6].

In the free TRAM flap, the flap vessels are ligated and microsurgically re-anastomosed commonly with the internal mammary and sometimes with the thoracodorsal vessels. With free flaps, the options range from complete TRAM flaps (skin, fatty tissue, and rectus

abdominis muscle), muscle sparing TRAM flaps (skin, fatty tissue, and a small portion of the rectus abdominis muscle) to isolated perforator flaps such as DIEP flaps (skin, fatty tissue, and the deep inferior epigastric artery), and superficial inferior epigastric artery or SIEA flaps (skin, fatty tissue and the superficial inferior epigastric vessels), which have become very popular.

The LD flap is a pedicled flap often used to reconstruct moderate-sized to small breasts in combination with silicone or saline implants. This flap contains skin, fat, the latissimus dorsi muscle, and the thoracodorsal vessels [6], with the arteries and veins still attached. Therefore, it is a pedicled flap rather than a free flap (Figs. 3A and 3B).

Normal and Benign Imaging Findings after Autologous Breast Reconstruction

Since flaps are composed mainly of fatty tissue, reconstructed breasts demonstrate primarily fatty tissue on mammography, ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI) (Fig. 4). The muscular component of the flap can be seen on mammography, CT and MRI as a density with associated vessels in the posterior region of the reconstructed breast, anterior to the pectoral muscle.

Post-surgical complications

Post-surgical complications following autologous reconstruction include seromas, hematomas, and infections. Seromas are fluid collections commonly seen in the early post-operative period. They are often seen on ultrasound as anechoic (Fig.5) or complex fluid collections that tend to resolve over time [7]. Israeli et al. [8] found that LD flaps are more prone to seromas than TRAM flaps, whereas TRAM flaps are associated with more perfusion-related complications, such as skin necrosis and fat necrosis.

Hematomas are also seen in the early post-operative period. The sonographic appearance of hematomas depends on the state of degradation of the blood products. The sonographic appearance of hematomas is varied, including hyperechoic, cystic and complex cystic masses with internal debris and echogenic walls [9].

The incidence of infection following reconstruction ranges between 2 and 4% [10]. Ultrasound is usually required to differentiate between mastitis and an abscess. Abscesses on ultrasound are shown as irregular, oval cystic masses with internal debris and surrounding subcutaneous edema (Fig. 5). On Doppler ultrasound, the cyst wall is thick with increased vascularity [9]. Hence, sonography remains an important diagnostic tool in the immediate to subacute post-operative period following myocutaneous flap reconstruction.

Other benign findings, including epidermal inclusion cysts and fat necrosis, may appear after reconstructive surgery. While there are certain features, as detailed and illustrated below, which may strongly suggest these lesions; needle biopsy may be needed to establish the correct diagnosis.

Epidermal Inclusion Cysts

Epidermal inclusion cysts are formed by a proliferation of squamous cells implanted in the dermis. Since epidermal inclusion cysts have been reported secondary to trauma such as reduction mammoplasty [11], epidermal inclusion cysts may also be seen following autologous myocutaneous flaps surgery. The sonographic features of epidermal inclusion cysts are varied. These cysts may appear as cystic, complex, or hyperechoic masses. They also may mimic solid masses (Fig. 6), but close contiguity with the skin and the absence of vascularity suggests a diagnosis of an epidermal inclusion cyst rather than a suspicious solid mass [12]. Extension of these masses into the dermal layer has been reported as a specific sonographic finding of epidermal inclusion cysts [13]. Careful evaluation of these superficial masses is necessary since the most common sites of recurrences in the reconstructed breast are the skin and the subcutaneous tissues [14].

Fat necrosis

Fat necrosis is the most common cause of palpable and nonpalpable lesions in the reconstructed breast. The clinical manifestations of fat necrosis in reconstructed breasts include impaired wound healing and palpable areas suspicious for cancer recurrence, leading to biopsies and increased patient anxiety [15]. Prior studies have shown a higher rate of fat necrosis with DIEP flaps than with muscle-sparing TRAM flaps [16]. The higher likelihood of developing fat necrosis in DIEP flaps is related to the number of perforators harvested for the flap. The fewer perforators used, the more ischemic and more susceptible to fat necrosis the flap is. Fat necrosis lesions are usually located at the periphery of autologous flaps, such as at the parasternal and superior regions of the chest wall, where the blood supply is less robust [17]. In a study of 365 flaps, fat necrosis masses were more frequent within the early post-operative period with an average of three months after surgery, and they represented 94% of the masses in the first year, whereas recurrent breast carcinomas tended to present later [18].

Fat necrosis has a wide range of mammographic features, including radiolucent masses, focal asymmetries, calcifications, and spiculated masses [19]. In the reconstructed breast, peripheral location of the lesion [17, 18], along with central fat content is an important clue. Fat necrosis is characterized by a central radiolucent appearance on mammography, and fat signal on non-fat saturated sequences on MRI (Fig. 7). On ultrasound, fat necrosis appears as cystic, complex, or solid masses, sometimes indistinguishable from malignancy [20]. On MRI, fat necrosis findings ranges from typical hyperintense lesions on non-fat saturated T1-weighted sequences to spiculated enhancing lesions (Fig. 8) suspicious for malignancy [21]. Due to the high prevalence of fat necrosis in patients with autologous myocutaneous flaps, our MRI protocol for these patients includes a non-fat saturated T1-weighted sequence or an optional fat-water separation technique such as the Iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL) to better demonstrate the fatty component. If fat necrosis is palpable, placement of a palpable marker enables correlating the abnormality with a macroscopic fat-containing lesion, and allows for accurate diagnosis without the need for biopsy. Despite all efforts for a non-invasive diagnosis, a biopsy may be needed in the absence of demonstrable fat, given the frequent overlap in imaging characteristics of fat necrosis and recurrent breast cancer.

Reconstruction with Implants and Associated Complications

Implant-based reconstruction may be a one--step or a staged procedure. Staged procedures involve the use of expanders with adjustable volume to stretch the skin at a later time and not compromise any blood supply to the mastectomy skin flaps at the time of surgery (Fig. 9). This process also allows the patient's participation in determining the final breast size. When expansion is complete, the expander is replaced by a fixed-volume implant [22]. In the United States, breast implant reconstruction is favored over autologous breast tissue, owing to its lower morbidity rate and the shorter operative time. Autologous flap reconstructions are more complex and require skilled plastic surgeons [23].

Implants used for breast reconstruction are either silicone or saline, with some variants such as stacked implants, which are rarely performed, or double-lumen implants which are no longer available in the United States [24, 25]. A subpectoral location is recommended to decrease the risk of scar contracture around the implant.

Complications associated with staged procedures are more frequent in the initial phase when the expander is placed. The most common complications are dehiscence and necrosis [26]. Other complications include infection, hematoma, seroma, deflation, extrusion, rupture, and capsule formation with contracture (Fig.10). Capsular contracture is usually a clinical diagnosis, although its presence may be inferred by imaging, and commonly occurs in patients who have undergone radiation therapy [27].

Malignant Imaging Findings after Autologous or Implant-Based Reconstruction

Recurrent Breast Cancer

Although a mastectomy removes most of the tissue in the breast, breast cancer may recur in the remaining tissue. The rate of local recurrence in a reconstructed breast is 5%–15% [28]. Factors that increase the risk of breast cancer recurrence include the presence of lymphovascular invasion, young age, high tumor grade, large tumor size, narrow margin width, and multicentricity (18). Breast cancer recurrences after reconstruction are most commonly located in the skin or the subcutaneous tissues, where they are often easily detected by palpation. The second most common site of recurrence is deep adjacent to the pectoralis muscle (Fig.11), where the autologous tissue or the implant may camouflage the recurrence. These more deeply located recurrences are usually detected by ultrasound, MRI, or positron emission tomography (PET)-CT. The location of the local recurrence affects the patient's overall survival, with chest wall recurrences having a poor prognosis and more likely associated with distant metastases [29]. Recurrent breast cancer in the reconstructed breast and primary cancer in the native breast have similar imaging features [30]. On mammography, recurrences can be seen as irregular masses, suspicious calcifications, or skin thickening. Sonographically, recurrences are often seen as irregular, vascular masses with spiculated margins. However, recurrent breast cancers can demonstrate a benign appearance and even simulate a post-operative collection; therefore a high level of suspicion regarding any solid mass is recommended [31].

Recurrent cancers on MRI usually exhibit hypointense signal on T1-weighted images, intermediate to high signal intensity on T2-weighted sequences, and avid enhancement (Fig. 11), on post-contrast sequences [32]. PET-CT is not recommended for surveillance but is helpful for ruling out distant metastases when a recurrence is suspected [33]. Recurrent breast cancer usually shows fluorodeoxyglucose F18 (^{18}F FDG) uptake.

Current evidence supports taking an interval history and performing a physical examination every 4–6 months for 5 years after treatment and then annually thereafter [34]. However, no optimal modalities for detecting breast cancer recurrence have been determined [35]. The use of mammography in the reconstructed breast has been controversial. Mammography has been advocated to be used in breast reconstructions with autologous tissue flaps rather than in breast reconstructions with implants. Helvie et al. [36] showed that mammography can aid in the detection of breast cancer recurrence before clinical examination in breast reconstruction with TRAM flaps, with a recurrence rate of 2.8% in those who were evaluated with mammography within a 2-year period. However, this rate is comparable to recurrences detected by physical examination in a study conducted by Howard et al. [37], with a recurrence rate of 3.9%. Therefore; mammography is not recommended for routine post-operative evaluation of the reconstructed breast.

At our institution, the diagnostic approach to a palpable abnormality in the reconstructed breast starts with an ultrasound evaluation. Lesions having internal calcifications are also evaluated with mammography. The aim of imaging in palpable recurrences is to help determine the extent of the malignancy and to facilitate local excision, thereby avoiding the loss of entire myocutaneous flap or chest wall. MRI is helpful in determining the depth of invasion and involvement of adjacent structures- such as involvement of the sternum in parasternal recurrences.

Breast Sarcomas

Sarcomas of the breast rarely occur in patients with breast cancer who have undergone radiation therapy. The latency period ranges from 3 to 20 years. Although the risk of developing breast sarcoma after breast reconstruction is exceedingly rare, the prevalence of these sarcomas will increase as patients live longer due to advances in surgical and radiation therapy [38]. A few case reports have described sarcomas in the reconstructed breast [39, 40]. The imaging features of these sarcomas are similar to those of sarcomas that develop in the native breast tissue [41], with the exception of secondary angiosarcoma that tends to affect the skin [42]. Ultrasound usually shows breast sarcomas as large, heterogeneous, solid masses with increased vascularity. CT and MRI usually are more helpful for delineating the disease extent for surgical planning than ultrasound. On MRI, breast sarcomas are heterogeneous on T1-weighted images, hyperintense on T2-weighted images (Fig.12), and markedly enhancing on post-contrast sequences [43]. On PET-CT images, avid uptake of ^{18}F FDG is seen in high-grade sarcomas, whereas low uptake of ^{18}F FDG is seen in low-grade sarcomas [44].

Conclusion

Although patients with reconstructed breasts are usually followed with regular physical examinations, no clear guidelines have been established for imaging follow-up of these patients. An understanding of breast reconstruction techniques and the imaging features of the reconstructed breast will enable radiologists to interact effectively with plastic surgeons and breast surgeons and to avoid delays in the diagnosis of breast cancer recurrences or sarcomas. Seromas and abscesses are the most common complications following implant reconstruction, and they are usually diagnosed by ultrasound, while delayed complications such as implant rupture or capsular contracture are best addressed by MRI and clinical assessment, respectively. Fat necrosis may require a multimodality approach to diagnosis, and its key feature is the demonstration of macroscopic fat by mammography or MRI. Lastly, recurrent cancers in the reconstructed breast are frequently identified on clinical examination, with the role of routine imaging surveillance not clearly established. The aim of imaging is to establish the disease extent, and to help facilitate local excision to prevent the loss of a breast reconstruction.

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Fig.1.

Pedicled and free TRAM flaps. A) The pedicled flap rotates the abdominal tissue to the chest wall with its blood supply. The pedicled flap contains skin, fatty tissue, and muscle. B) The free flap vessels are ligated and microsurgically anastomosed to the chest vessels. The free flap contains skin, fatty tissue, and vessels.

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Fig.2. Abdominal vascular anatomy. The deep vessels are the superior epigastric vessels and the deep inferior epigastric vessels. These vessels have perforators that supply the overlying fat and the skin. The superficial network is supplied by the superficial superior epigastric vessels and the superficial inferior epigastric vessels.

A

B

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Fig.3.

A) LD flap reconstruction. This flap uses the LD muscle and a portion of the overlying skin and fat. The arteries and veins remain attached.

B) 52-year-old woman with a history of ductal carcinoma in situ (DCIS), status post mastectomy with reconstruction with a latissimus dorsi flap. Sagittal T1-weighted post-contrast MRI shows the muscle fibers of the flap (thick white arrows). Blood vessels are also noted within the muscle pedicle (dashed white arrow).

Fig.4.

Normal appearance of a TRAM flap in a 44-year-old woman with a history of right breast cancer who underwent bilateral mastectomies and bilateral reconstructions with free TRAM flaps. A) Left mediolateral oblique mammogram of the reconstructed breast shows the predominantly fatty appearance with the surgical clips in the posterior region of the flap. B) Longitudinal ultrasound of the TRAM flap demonstrates fatty tissue. C) Chest CT demonstrates the typical changes of TRAM flap reconstructions. The reconstructed breast is fatty. A thin, soft-tissue curvilinear band is seen underneath the skin (white arrow). These bands represent the de-epithelialized abdominal skin of the flap that has been tunneled into position from the abdomen. D) Sagittal T1-weighted post-contrast MRI of the reconstructed breast demonstrates adipose tissue with no evidence of residual mammary tissue. The contact zone between the flap and the native tissue appears as a line of intermediate signal intensity (thin white arrow) parallel to the breast contour. A surgical clip is noted in the posterior region of the reconstructed breast (thick white arrow).

Fig.5.

48-year-old woman with DIEP TRAM flap reconstruction in the right breast after mastectomy for right breast cancer. She presented for evaluation of skin redness. Extended field of view ultrasound shows two fluid collections in the right reconstructed breast. In the central region, there is an anechoic fluid collection, consistent with a seroma (thick white arrows). In the medial region, where the skin demonstrated erythema, an irregular complex fluid collection is seen (dashed white arrows). Both collections were drained, yielding brownish fluid from the seroma and purulent material from the complex fluid collection, compatible with an abscess.

Fig.6.

58 year-old woman with a history of left breast cancer, status post bilateral mastectomies and reconstructions with DIEP flaps who presents for evaluation of a palpable abnormality.

A) Transverse US image in the area of the palpable abnormality shows a 1.7 cm circumscribed, superficial mass with posterior acoustic enhancement (white arrows). B) Power Doppler US shows minimal vascularity in the mass (white arrow). Ultrasound-guided FNA was performed, showing findings compatible with an epidermal inclusion cyst.

Fig.7.

Typical fat necrosis in a 53-year-old woman with a history of right breast cancer, status post mastectomy and reconstruction with a muscle-sparing free TRAM flap. A) Axial T1-weighted non-fat saturated MRI demonstrates a fat-containing mass in the upper outer quadrant (white arrows). B) Axial T1-weighted post-contrast MRI shows peripheral enhancement of the fat-containing mass (arrows). C) Extended field of view ultrasound shows a hypoechoic mass with indistinct margins (white arrows).

Fig.8.

44-year-old woman with a history of right breast cancer, status post mastectomy and reconstruction with a muscle-sparing free TRAM flap. A) Axial T1-weighted post-contrast MRI demonstrates a 1.3-cm oval enhancing mass in the pre-sternal fat (white arrow). B) Sagittal T1-weighted post-contrast MRI shows the enhancing mass (arrow) with an area of washout kinetics on the computer-aided diagnosis images. C) Longitudinal second-look ultrasound shows a hypoechoic mass with indistinct margins (white arrows). Ultrasound-guided-core biopsy demonstrated fat necrosis.

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Fig.9.

Implant-based breast reconstruction. After mastectomy, a tissue expander is placed under the muscle and the skin. Increasing amounts of saline are added to the tissue expander in the clinic. The fixed-volume implant is inserted after the tissue expander has been removed.

Fig.10.

50-year-old woman with a history of right breast cancer who underwent bilateral mastectomies with implant-based reconstruction. She presented for evaluation of hardening and pain in the reconstructed left breast. A) Extended-field-of-view ultrasound of the left implant demonstrates multiple folds (arrows). B) Sagittal T2-weighted MRI of the left breast shows the spherical appearance of the fibrous capsule and the creased shell (thin white arrow) as well as an implant effusion (thick white arrow). The patient underwent surgery, and capsular contracture was found.

Fig.11.

54-year-old woman with a history of DCIS who underwent reconstruction of the left breast with a free TRAM flap presented for evaluation of a palpable mass. A) Mediolateral oblique mammogram shows the post-surgical changes in the reconstructed breast. In the area of the palpable abnormality (triangle), a mass with indistinct margins and calcifications (arrow) is noted. B) Power Doppler ultrasound shows marked vascularity in the mass (arrows). C) Axial T1-weighted post-contrast MRI with fat saturation shows that the malignant mass (arrow) is avidly enhancing. Ultrasound-guided core needle biopsy showed invasive ductal carcinoma. D) PET-CT demonstrates that the malignant mass is hypermetabolic (arrow). The standardized uptake value was 4.3.

Fig.12.

53-year-old woman with a history of left breast cancer who underwent mastectomy with TRAM reconstruction presented with a palpable mass in the reconstructed breast. She received radiation therapy for her primary breast cancer. A) Left mediolateral oblique mammogram of the reconstructed breast shows a high-density partially imaged mass (arrows). B) Longitudinal ultrasound shows an 8-cm heterogeneous solid mass (arrows) occupying almost the entire reconstructed breast. C) Chest CT shows the 8-cm solid mass (arrows) adjacent to the chest wall. D) Axial T1-weighted post-contrast MRI depicts the heterogeneous enhancement of this mass (arrows). Surgical excision showed a matrix-producing sarcoma.