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Two-Stage Implant-Based Breast Reconstruction: An Evolution of the Conceptual and Technical Approach over a Two-Decade Period

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Abstract

Background—Over a two-decade period the senior author (P.G.C.) has had extensive experience with two-stage implant-based breast reconstruction with total musculofascial coverage. During this time period the approach has evolved substantially. The evolution has been based on changes in breast cancer treatment, available technology and most importantly, on yearly evaluation of surgical outcomes.

Methods—This paper describes changes in the conceptual approach to breast reconstruction, and the resulting evolution of surgical techniques. The evolution of concepts and current techniques are described as they relate to each consecutive stage of implant-based breast reconstruction.

Results—For the first stage of breast reconstruction, i.e. placement of the tissue expander, key concepts and techniques described are the vertical mastectomy defect, the point of maximal expansion, the musculofascial pocket, and the inferior fasciotomy. For the second stage of breast reconstruction, i.e. the exchange procedure, key concepts and techniques described are implant selection, setting the inframammary fold, defining the inferolateral shape of the breast, and circumferential capsulotomy.

Conclusions—The purpose of this article is to relay the lessons learned from this long experience and to provide conceptual and technical framework to two-stage implant-based breast reconstruction.

Introduction

Two-decades ago several basic concepts in oncologic treatment and breast reconstruction were already in effect. The evolution towards skin-sparing mastectomies preserved enough soft tissue to allow for implant-based breast reconstruction.¹ Tissue expanders and implants

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The remaining author has no financial interests or commercial associations to disclose.

Authors' roles

P.G.C. originated the novel surgical techniques described in this article. Both authors contributed to the conception of the article, and both participated in drafting and revising. Both authors gave final approval of the work, and both agree to be accountable for all aspects of the work.

had already undergone significant development allowing for their operative use.^{2,3} The concept of immediate breast reconstruction was well accepted.⁴ Since that time, rates of implant-based breast reconstruction have risen significantly.¹ Changes in oncologic practice, such as increased number of bilateral mastectomies, have contributed to the expansion of implant use.¹ Further, implant safety and technology have undergone significant improvements.^{5–9} Given the continued growth of implant-based breast reconstruction, it is imperative for reconstructive surgeons to have a strong conceptual and technical framework for two-stage breast reconstruction.

Over the past two-decades, the senior author has performed close to 5,000, two-stage breast reconstructions with total musculofascial coverage. During this extensive experience, his approach has evolved substantially. The evolution has been based on changes in breast cancer treatment, available technology, and, importantly, on evaluation of aesthetic results, complications and patient satisfaction.^{10,11} A breast reconstruction database containing clinical outcome data using these techniques has been maintained based on physical examination and patient interviews by the senior author. Early and late complications, aesthetic outcomes, and patient satisfaction resulting from these techniques were prospectively studied and previously reported.^{10,11} The aim of this paper is to detail the evolution of the concepts and surgical techniques that have been shown to create safe reconstructions with good to excellent long-term aesthetic results and high patient satisfaction.^{10–31} Below these concepts and technique are described, going consecutively through each stage of breast reconstruction.

Mastectomy Incision

Concept

Twenty years ago an oblique incision that placed the medial aspect of the mastectomy scar as inferior as possible was used [Figure 1]. The principle was to avoid placing the incision anywhere near the visible cleavage. Our experience, however, was that this approach placed a medial dog-ear where it was hard to correct. Further, expansion under the oblique incision was hindered, especially in the lower pole.

Surgical Technique

Given these observations, the current approach is a horizontal incision extending as little as possible medially. This minimizes the medial dog-ear and maximizes the amount of lower pole skin that can be expanded, unhampered by an overlying scar.

For nipple-sparing mastectomies, the preference has been a periareolar incision with lateral extension [Figure 1]. In the experience at Memorial Sloan Kettering, this incision improves exposure during the mastectomy and minimizes ischemic mastectomy flap and NAC complications.^{32,33} Across institutions this data remains inconsistent.^{34,35} This incision, compared to the inframammary incision, also allows for the best access during the exchange procedure for reconstruction of the fold and circumferential capsulotomy.

The Mastectomy Defect

Concept

In skin-sparing mastectomies the patient undergoes excision of a horizontal ellipse of skin, leaving a vertical skin deficit [Figure 2]. To reconstruct a vertical skin deficit, the surgeon needs to direct the bulk of expansion along the vertical dimension of the breast [Figure 2].

Surgical Technique

To maximize expansion in the vertical direction, full-height expanders are preferred. For any given base width, a full-height expander maximizes the overall volume of expansion and provides more expansion in the needed vertical dimension. The base width of the tissue expander is selected to maintain the patient's actual base width. This is measured intraoperatively, inside the mastectomy pocket, after the mastectomy.

Tissue Expander Placement

Concept A: Point of Maximal Expansion

The approach to placement of the tissue expander has undergone a significant evolution. Initially anatomic expanders, which are designed to be placed at the level of the inframammary fold were used. The hope was that, with preservation of the inframammary fold, both the shape of the expander and the position and contour of the inframammary fold would be maintained during the expansion.³⁶ Ideally, the point of maximal expansion would be in the lower third of the breast. In this ideal case, the anatomic expander could then be replaced with an anatomically shaped implant of the precise size and contour.^{7,37}

In reality, placing the expander at the inframammary fold generally caused the point of maximal expansion to be too high, creating a breast shape that looked very constrictive in the lower pole. The expansion is higher than desired because the chest tissues tighten around the expander as the volume increases. The pressure within the expander also increases, so the device expands into a round shape rather than into its ideal anatomic shape. The point of maximal expansion thus travels closer to the midpoint of the expander rather than staying at the desired lower pole [Figure 3, *center*]. To address this problem, the expander is now placed more inferiorly. Placing the expander more inferiorly also minimizes overexpansion of the upper pole and maximizes expansion of the lower pole.

Surgical technique

Using a full-height expander, the surgeon places the inferior border of the expander one to two centimeters below the inframammary fold. In this location, the point of maximum expansion (at the center of the expander) is at the desired position in the lower third of the final reconstructed breast [Figure 3, *right*]. Medially the recommended boundary for a full-height tissue expander is about one to two centimeters from the midline, and laterally the boundary is at the anterior axillary line.

Concept B: Musculofascial Pocket

The traditional approach to creating a pocket for the expander and implant is to optimize muscle coverage.³⁸ Accordingly, both the pectoralis major and the entirety of the serratus were initially raised.³⁹ Dissection of the pectoralis major muscle is easy and minimally traumatic to the patient. However, raising the serratus muscle completely off the ribs leaves a surface overlying the chest wall that is painful and not ideally suited for the sutures that would subsequently define the inferolateral aspect of the reconstructed breast. Thus, the approach has evolved to creating a **musculofascial pocket**. Superiorly, the musculofascial pocket includes the entirety of the pectoralis muscle, but laterally it includes only a portion of the serratus muscle with the entirety of its overlying fascia. Similarly, for inferior coverage, there is great variability in where the pectoralis inserts on the chest wall. In patients whose pectoralis ends above the inframammary fold, total submuscular coverage with the pectoralis muscle forces the tissue expander to be placed too high. To address this problem, the **musculofascial pocket** inferiorly includes the rectus fascia. This ensures inferior coverage of the expander while allowing the expander to be placed low enough to achieve expansion of the inferior pole [Figure 4]. A musculofascial pocket provides well-vascularized fascia and muscle to completely cover the expander and implant. This approach provides two benefits. First, the pocket provides structural support to the expander and the final implant, ensuring long-term success of the reconstruction. Second, the well vascularized tissue of the musculofascial pocket forms a protective layer that allows for good expansion and may prevent loss of the reconstruction caused by necrosis of the mastectomy flap.²⁷ Use of acellular dermal matrices and other nonvascularized slings are avoided in favor of the healthy vascularized musculofascial pocket.

Surgical Technique

To create a musculofascial pocket the pectoralis major muscle is raised superiorly. Next, the serratus muscle and its overlying fascia are raised in a plane within the muscle. This leaves some muscle on the chest wall and elevates some muscle with the overlying fascial layer. Enough of the muscle should be raised so that the serratus fascia and/or muscle maintains the expander in good position and prevents it from extruding into the axilla. Finally, the rectus fascia is raised inferiorly and in continuity with the serratus fascia. With this dissection adequate space should be created to place the tissue expander without allowing it to fold on its self.

Concept C: Inferior Fasciotomy

As previously discussed, the inferior extent of dissection is usually one to two centimeters below the inframammary fold in order to allow expansion of the lower pole and avoid over expansion of the upper pole. In practice, however, it became apparent that this expansion is often limited by a band of fascia that almost always lies across the lower pole. By preventing anterior expansion, this band flattened the lower pole in the final implant reconstruction and at times pushed the expander inferiorly or superiorly during expansion.

Surgical Technique

To solve this problem the approach was altered to making a curvilinear fasciotomy through inferolateral fascia into the subcutaneous fat, at or just below the inframammary fold [Figure 5]. The position of the expander will be submuscular superior to the fasciotomy and subcutaneous inferiorly. After performing the inferior fasciotomy, it is very important for the surgeon to insert his or her hand and pull anteriorly to make sure that there are no remaining bands of fascia inferiorly. Even a small band will become constricting and will prevent anterior expansion. By allowing for anterior expansion, the inferior fasciotomy prevents superior and inferior migration of the expander which occurred more frequently prior to this modification.

This approach has maximized the aesthetics of the results with two-stage breast implants, so it represents a significant evolution in the technical approach. Once the pocket is complete the tissue expander is placed and the pectoralis muscle is re-sutured the serratus muscle. This maintains the original position of the pectoralis muscle and prevents window shading.

Concept D: Intraoperative Expansion

Twenty years ago, at the completion of the mastectomy, the amount of fluid placed in the tissue expander was very small so as to avoid mastectomy flap necrosis.⁴⁰ Over time, however, the volume placed intraoperatively was increased to expedite the expansion process and to decrease risk of postoperative hematoma and seroma. The increase in intraoperative fill did not increase the rate of mastectomy flap failure.^{10,11}

Surgical Technique

The current practice is to fill approximately 50% of the total volume of the expander at the time of mastectomy, unless the mastectomy flaps and/or the musculofascial pocket do not look healthy or strong enough to tolerate this.

Postoperative Expansion

Concept

The senior author has gravitated towards expanding the expander earlier and more quickly.⁴¹ This approach generally makes expansion easier. The longer one waits to expand, the more scar and constriction occurs, and expansion often becomes more difficult after 6–8 weeks.

In accordance with the trend in the late 1980's, we would initially over-expand the expander by 50–100% of the final volume of the implant. However, observations of outcomes over time revealed that over-expansion was associated with rippling as well as excessive thinning of the skin, particularly in the upper pole. Moreover, after beginning to use the inferior fasciotomy, the lower pole expanded more easily, obviating the need for substantial over-expansion.

Surgical Technique

Based on these observations, the current practice is to over-expand the device by about 10–20%. The first outpatient expansion begins about 10–14 days after the mastectomy and

around the time when the drains are removed. The expander is expanded with 60–120 mL weekly;⁴¹ the volume is based clinically on the quality of the mastectomy flaps and patient tolerance.

Tissue Expander Exchange for Implant

Concept A: Timing

The exchange to final implant is generally performed at least six weeks after the final expansion and four weeks before radiation, in accordance with the protocol developed at Memorial Sloan Kettering.^{21–23} There are several exceptions to this timing, dictated by the oncologic approach [Figure 6].

Concept B: Implant Selection

During the expansion process, the surgeon should clarify the patient's expectations on final breast volume, contralateral procedures, and the type of implant. Our preference is to use anatomically shaped implants. Although round implants can be appropriate for augmentation, our impression is that they generally do not provide the best aesthetic outcome for breast reconstruction. Until 2006, when the FDA lifted its moratorium on silicone implants,⁶ the senior author generally used an anatomically shaped saline implant. As form-stable cohesive silicone gel implants were developed, several important advantages to this type of implant became evident. The first advantage is the great variety of sizes, contours, and shapes. This allows patient and surgeon to choose the look of bilateral reconstructions and allows a superior ability to provide symmetry in unilateral reconstructions. The second advantage to form-stable implants is that the cohesive gel is more likely to maintain its shape and contour and is much less likely to ripple.^{5,7–9}

Shaped anatomic implants for a given patient are chosen to have the appropriate base dimensions (height and width) and to allow for the appropriate ultimate projection. Patients and their breasts are generally short and wide or tall and thin; similarly the base dimensions of an implant can be short and wide or tall and narrow. The base width is chosen to maintain the patient's actual base width measured intraoperatively at the first stage and used to select the base width of the tissue expander. The final volume from the expansion is also used as a reference for final implant volume. The real question is how short or how tall and how much projection. Experience and use of sizers will optimize aesthetic outcomes.

Concept C: Setting the Inframammary Fold

The exchange procedure is performed with the patient in the sitting position so that the ultimate position of the implant(s) is visualized by the surgeon in just the same manner at the patient would see herself in a mirror while standing up [Figure 7].

An important part of the exchange procedure is setting the inframammary fold and the inferolateral extent of the implant pocket. The inframammary fold is the most critical visual landmark of the breast, and the entire final reconstruction is based upon this landmark. Thus, we have gravitated toward reconstructing the inframammary fold as the first major step in the operation. In addition, we now reconstruct the inferolateral base of the breast to prevent

the implant from migrating toward the axilla, which can be extremely bothersome to the patient.

Surgical Technique

The arms and head are taped so that the patient can be seated safely in the operative room. The implant is removed and the inframammary fold is set using a zero silk suture that fixes the deep dermis to the anterior chest wall. Although initially the sutures were placed into the periosteum, this is extremely painful to patient, and over time he observed that it is unnecessary. Thus the suture on the chest wall is generally placed in the capsule and in the soft tissues that overlie the chest wall and the ribs. Several sutures are placed in order to precisely reconstruct the shape of the fold. Once the level of the inframammary fold is set, the same technique is used to create an aesthetically pleasing curve inferolaterally [Figure 8]. This defines the inferolateral shape of the breast and creates a fixed boundary that prevents the implant from migrating laterally. After these sutures are placed, the breast envelope begins to take shape. Long-term experience with this technique has demonstrated that the inframammary fold and the inferolateral border of the implant pocket will remain fixed over time.

Concept D: Circumferential Capsulotomy

Circumferential capsulotomy represents the most important advancement in our approach to the exchange procedure. Initially, no capsulotomy was performed if the implant was positioned correctly in the expansion pocket. Instead, the capsule would be selectively released where it appeared tight. The long-term outcomes with this approach, however, were invariably poor. Limited capsulotomies led to herniation of the implant into the location of the capsulotomy, while the rest of the capsule continued to tighten even further, leading to odd shapes and contours. Thus, our standard practice is now to ensure anterior release by performing a circumferential capsulotomy. Of note, the literature very commonly mentions “radial scoring” of the capsule. True radial scoring allows centripetal release, but not anterior release, of the breast. Therefore, radial scoring is performed for a constricted tuberos breast, but not for the typical contracture around an implant, which tends to be more in the anterior-posterior dimension [Figure 9].

Operative Technique

To perform the circumferential capsulotomy, the capsule is released at a distance from the chest wall that releases its tightest portion. This is very similar to performing a burn contracture release at the point of maximum tension. In many cases, the tightest portion of the capsule is one to two centimeters anterior to the chest wall, but it varies from patient to patient. Even within the same pocket, the tightest portion can be at different distances from the chest wall. During the capsulotomy, special attention should be paid to the lateral axillary region and to the pectoralis muscle inferomedially. If the pectoralis major is tight inferomedially, it may need to be released into the subcutaneous fat. The extent of this release is based on an aesthetic evaluation of the medial contour of the final reconstructed breast. It is also important to release scar overlying the axilla, which is especially bothersome and noticeable in both radiated patients and in those who have received axillary dissections.

Circumferential capsulotomy maximizes the projection of the breast. After a complete and properly performed circumferential capsulotomy, the anterior release of overlying soft tissue envelope can be from as little as one centimeter to as much as seven centimeters. It is important to pull forward on the overlying musculofascial and cutaneous envelope to make sure this release is circumferential and that it creates an overlying envelope that will comfortably drape over the implant. The location of draping over the implant does not change significantly after the exchange. Thus, the draping needs to be optimized at the time of the exchange in order to optimize the result. If the inframammary fold is reconstructed as described above and the capsulotomy and release is complete, then the overall result will be long lasting.

Concept D: Use of Sizers and Drains

Sizers are mostly used to estimate volume; however, anatomic sizers can also help the novice select dimensions for the anatomic implant, evaluate adequacy of the capsulotomy, and make sure that the newly created inframammary fold and inferolateral breast boundary result in a soft tissue envelope that conforms to the implant. When anatomic implants are used, the soft tissue envelope should fit snugly around the implant to prevent rotation and malposition.⁷ By the end of the exchange procedure, it is critical to achieve the best result visually, as the result generally does not change with time.

Operative Technique

Sizers are chosen based on the base width of the implants with volumes that closely approximate the preoperative expectations of the patient and surgeon. After the fold and inferolateral boundary of the breast have been set, the sizers are used to confirm final implant volume. The sizer is then used to decide whether contour irregularities and constrictions still exist and therefore whether the overlying envelope needs further release. Once the capsulotomies are finalized, additional silk sutures may be placed along the inframammary fold and inferolateral breast to create a pocket that will very closely approximate the shape of the sizer and eventually the final implant. The appropriate implant is then placed with the base footprint sitting exactly in the desired position. If the implant is shaped, it should precisely fit within the musculofascial envelope. Once the final implant has been placed, a closed suction drain is used to prevent seroma formation.

Conclusion

For two decades the senior author has routinely evaluated patients on a yearly basis to analyze and document the outcome of each surgical step in implant-based breast reconstruction. His understanding of the shortcomings of certain steps have contributed to each step of the evolving approach described [Figure 10–11]. We hope that lessons learned and the resulting surgical techniques can be of use to novice surgeons as a platform for their approach to breast reconstruction and to experienced surgeons as a source of possible improvement in their approach.

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Figure 1. Mastectomy incisions

An oblique incision used for skin-sparing mastectomy places the medial aspect of the mastectomy scar inferiorly away from the visible cleavage line (*left*). The tradeoffs are a medial dog ear, which is hard to correct, and difficulty in expanding the lower pole, which can lead to distortion of contour. The current approach for skin-sparing mastectomies is a horizontal incision (*center*). This incision minimizes both the medial dog ear and distortion of breast contour. For nipple-sparing mastectomies, the preferred incision is a periareolar incision, with or without a small lateral extension (*right*). ©2015, Memorial Sloan Kettering Cancer Center.

Figure 2. The mastectomy defect

After a transverse elliptical skin excision, the skin deficit is a vertical deficit (*left and center*). To compensate for the vertical deficit, expansion should be directed in the vertical dimension (*right*). ©2015, Memorial Sloan Kettering Cancer Center.

Figure 3. The point of maximal expansion

The ideal point of maximal expansion occurs at the lower third of the breast (*left*). The ideal point of maximal expansion is indicated by the red horizontal line drawn across the associated figures. In reality, if the expander is placed at the inframammary fold, the point of maximal expansion occurs close to the midpoint of the filled tissue expander. This point of maximal expansion is too high to recreate a natural breast contour (*center*). Placing the expander more inferiorly will place the point of maximal expansion at the desired lower pole of the reconstructed breast (*right*). ©2015, Memorial Sloan Kettering Cancer Center.

Figure 4. The musculofascial pocket

The musculofascial pocket is represented in blue, and fascia are represented by areas enclosed in dotted lines. The musculofascial pocket includes the entirety of the pectoralis muscle and fascia superiorly, inferiorly it extends 1-2cm below the IMF thus, depending on how high the pectoralis ends, it may or may not include the rectus fascia, laterally it extends to the anterior axillary line under a portion of the serratus muscle with the entirety of its overlying fascia. ©2015, Memorial Sloan Kettering Cancer Center.

Figure 5. Inferior fasciotomy

To maximize expansion at the lower pole, an inferior band of fascia is released at, or 1-2 cm below, the inframammary fold (*left*). This curvilinear inferior fasciotomy goes through the musculofascial pocket into the subcutaneous fat. After the inferior fasciotomy, the tissue expander should be in a sub-muscular fascial position superiorly but in a subcutaneous position inferiorly (*right*). ©2015, Memorial Sloan Kettering Cancer Center.

Figure 6. Timing algorithms for two-stage breast reconstruction with radiotherapy (XRT)
 Current algorithms for two-stage implant breast reconstruction. Implant-XRT algorithm followed for patients receiving radiation to the final implant (*left*). (Adapted from Cordeiro PG et al.²¹) TE-XRT algorithm is followed for patients receiving neoadjuvant chemotherapy and radiation to the tissue expander (*right*). (Adapted from Cordeiro PG et al.²²) TE, tissue expander. XRT, radiation.

Figure 7. Patient positioning

The exchange procedure is performed with the patient in the sitting position so the ultimate position of the implant is seen by the surgeon as the patient would see herself in a mirror while standing up (*left*). The arms and head are taped such that the patient can be safely seated during the operation (*left and right*). ©2015, Memorial Sloan Kettering Cancer Center.

Figure 8. Setting the inframammary fold

The inframammary fold is reconstructed using a zero silk sutures that fixes the deep dermis to the anterior chest wall. Several sutures are placed to precisely reconstruct the shape of the fold. Once the inframammary fold is reconstructed, the soft tissue envelope begins to take on the shape of a breast without a sizer or implant (*right*).

Figure 9. Coronal view of circumferential versus radial capsulotomy

Circumferential capsulotomy will result in anterior release of the overlying soft tissue envelope. This maximizes projection of the breast (*Left, top and bottom*). “Radial scoring” results in centripetal release of the breast, which is helpful when treating a constricted breast. However, radial scoring does not result in the desired anterior release that creates breast projection (*Right, top and bottom*). ©2015, Memorial Sloan Kettering Cancer Center.

Figure 10. Unilateral two-stage reconstruction

Post-operative view after two-stage left implant-based reconstruction using the senior author's current techniques.

Figure 11. Unilateral two-stage reconstruction after nipple sparing mastectomy
Post-operative view after two-stage right implant-based reconstruction using the senior author's current techniques. Patient underwent right nipple sparing mastectomy with immediate tissue expander placement followed by expander exchange for implant.