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SPECIAL TOPIC
Breast

Careful Where You Cut: Strategies for Successful Nerve-preserving Mastectomy

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Summary: Breast neurotization represents an evolving technique that is not widely practiced in most centers specializing in breast cancer treatment. Recognizing the limited educational resources available for breast and plastic surgeons concerning mastectomy techniques that emphasize nerve preservation, our study sought to bridge this gap. Specifically, we aimed to provide a comprehensive exploration of the surgical applied anatomy of breast sensory innervation and a detailed, step-by-step guide for incorporating nerve-sparing mastectomy and breast neurotization into clinical practice. The significance of this work lies in its potential to enhance the understanding and implementation of nerve-preserving techniques in mastectomy procedures, contributing to improved patient outcomes and quality of life post surgery. We hope that by familiarizing breast and reconstructive surgeons with this procedure, we can gain momentum in our research efforts and ultimately enhance the care provided to mastectomy patients. *(Plast Reconstr Surg Glob Open 2024; 12:e5817; doi: 10.1097/GOX.0000000000005817; Published online 15 May 2024.)*

INTRODUCTION

Advancements in the fields of breast surgical oncology and plastic surgery have revolutionized the approach to mastectomy procedures, allowing for the integration of oncological principles with a focus on achieving aesthetic outcomes. One such pioneering technique is nipple-sparing mastectomy (NSM), which has become the default choice for many breast cancer patients requiring mastectomy. NSM preserves the nipple, the central focal point of the breast, resulting in a postoperative appearance closely resembling the patient's natural breast. Importantly, long-term follow-up studies over 5, 10, and 15 years reveal that NSM demonstrates no significant differences in overall survival or breast cancer-specific survival when compared with total mastectomy, thus affirming its oncological safety.[1,2]

Although NSM offers remarkable cosmetic benefits by preserving the nipple, it is not without its challenges. Many patients express disappointment due to the diminished sensation and numbness that often follows the procedure. This issue gained national attention in 2017 when *The New York Times* published an article titled "After mastectomies, an unexpected blow: numb new breasts."[3]

The restoration of sensation after mastectomy has been reported, albeit with varying rates of success.[4–13] The absence of sensory perception in the chest wall or reconstructed breast not only impacts a patient's psychological well-being but also presents the risk of potential thermal injuries due to the lack of protective sensation.[14–16]

Reconstructive surgery has recognized the need for techniques to restore sensation, and recent developments have extended neurotization procedures beyond autologous reconstruction to implant-based procedures.[11,17–23] In 2019, Peled and Peled published a pivotal article on nerve preservation and allografting for breast neurotization during NSM and immediate implant reconstruction, reporting promising initial outcomes.[11] Djohan et al also found improvements in breast skin and nipple sensation after nerve preservation and allografting.[17]

Successful breast neurotization during NSM and implant-based reconstruction requires a close collaboration between breast and plastic surgeons.[24–26] This collaborative effort hinges on two critical components: nerve-sparing mastectomy with the preservation of lateral

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and medial superficial intercostal nerve branches (ICN) and the neurotization of the nipple–areola complex (NAC). Precise identification and preservation of sensory nerve branches during mastectomy are paramount, underscoring the necessity of a thorough understanding of the anatomy and trajectory of these nerves.

Educational resources regarding mastectomy techniques that maximize nerve preservation are currently limited. This article aims to address this gap by providing an in-depth exploration of the surgically applied anatomy of breast sensory innervation and a step-by-step guide for integrating nerve-sparing mastectomy and breast neurotization into clinical practice.

APPLIED SENSORY ANATOMY OF THE BREAST

The breast receives its innervation primarily from the third to fifth intercostal nerves through medial and lateral branches.[27–31] These intercostal nerves originate as mixed nerves, carrying both sensory and motor fibers, and travel alongside the vascular bundle located at the inferior border of the superior rib. Their trajectory proceeds from posterior to anterior, extending toward the chest (Fig. 1). These nerves then divide into two main branches:

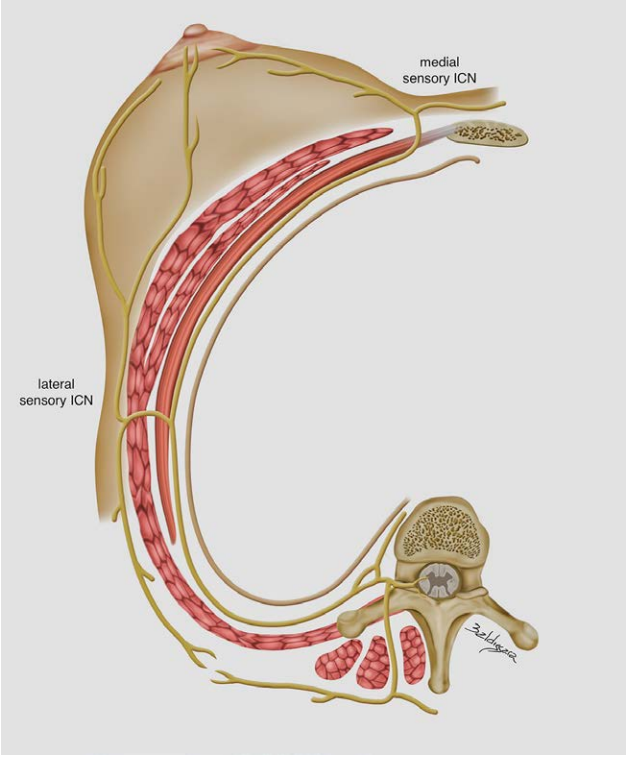

Fig. 1. The breast receives its innervation primarily from the third to fifth intercostal nerves through medial and lateral branches. These intercostal nerves originate as mixed nerves, carrying both sensory and motor fibers, and travel alongside the vascular bundle located at the inferior border of the superior rib. Their trajectory proceeds from posterior to anterior, extending toward the chest.

Takeaways

Question: Given the limited educational resources for breast surgeons on maximizing nerve preservation during mastectomy, this study intended to provide a guide for integrating nerve-sparing mastectomy and breast neurotization into clinical practice.

Findings: This article offers a comprehensive exploration of breast sensory innervation anatomy and a detailed guide for integrating nerve-sparing techniques, aiming to enhance patient outcomes and postsurgery quality of life by promoting broader adoption in mastectomy procedures.

Meaning: By offering a comprehensive guide, we aimed to improve postsurgery outcomes and quality of life for mastectomy patients through enhanced surgeon understanding and wider adoption of nerve-preserving techniques.

- ***Superficial branch (sensory):*** This branch penetrates the serratus muscle and provides sensory innervation to the lateral chest and breast.
- ***Deep mixed branch:*** Initially, this branch follows the ribs toward the medial chest. It eventually bifurcates at the level of the sternum-rib junction, with one branch accompanying the medial intercostal perforating vessels. This medial branch pierces the pectoralis muscle and offers sensory innervation to the medial chest.

The lateral intercostal branches are consistently located approximately 1–2 cm lateral to the lateral border of the pectoralis major muscle (Fig. 2). These nerves also divide into two branches, just before penetrating the serratus muscle. The first branch typically runs superficially in the subcutaneous tissue, while the second branch enters the breast tissue, further subdividing into several smaller nerve fibers.

The sensation of the NAC is intricate, with numerous sensory receptor endings at the areola[32]; among the third to fifth intercostal nerves responsible for NAC innervation, the fourth intercostal nerve predominates.[27–30] However, the trajectory of this nerve as it reaches the NAC can vary, with some branches running within the subcutaneous

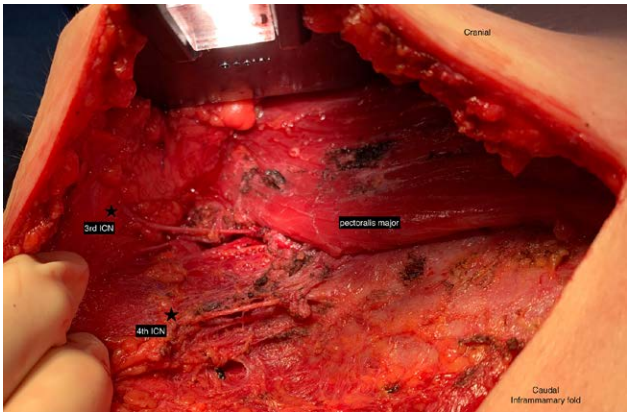

Fig. 2. The ICN can be found 1–2 cm lateral to the lateral pectoralis major muscle border.

tissue.[31] As such, there is potential to preserve this nerve during breast dissection.

Many intercostal nerve branches are often transected or damaged during traditional mastectomy procedures. Preserving superficial lateral and medial intercostal nerve branches is vital for enhancing sensory recovery in the mastectomy skin over time. Additionally, meticulous dissection of larger nerve branches into the breast tissue for a safe distance provides extra nerve length for neurotization of the NAC by the plastic surgeon.

In this section, we have outlined the sensory innervation of the breast, emphasizing the importance of preserving these nerves during mastectomy procedures. Preserving these nerves is a key component of successful breast neurotization, which we will elaborate on in subsequent sections.

SURGICAL TECHNIQUE

Nerve-sparing Mastectomy

The technique for nerve preservation can be successfully implemented during various types of mastectomy procedures. In our institution, this approach is most used in nipple-sparing mastectomies, which constitute approximately 84% of the cases we handle.[33,34]

The planning for nerve-preserving mastectomy begins with the selection of the incision site. This decision is made collaboratively between the plastic surgeon and the breast surgeon, balancing oncological considerations with the pursuit of optimal aesthetic outcomes. For most patients, we prefer an inferolateral fold incision.[30,31] However, patients with macromastia and/or grade 3 breast ptosis may benefit from a Wise pattern reduction incision, following principles described by Aliotta et al.[34]

An inferolateral inframammary incision offers better visualization and exposure of the lateral intercostal nerves. This approach has the added advantage of being less noticeable in the upright position. An inferior vertical incision from the 6 o'clock position at the edge of the areola extending inferiorly to the inframammary fold can also be a useful incision, especially for surgeons new to breast neurotization, as it provides good access to the subareolar area for distal nerve repair.

Successful nerve preservation in mastectomy involves identifying lateral intercostal nerves, evaluating those that can be safely preserved in subcutaneous tissue, and dissecting as much length as possible through the breast parenchyma. Some nerves may need to be transected, balancing oncological principles and technical feasibility. Identifying anterior branches that could potentially be preserved can be done during the lateral dissection of the mastectomy while dissecting around the lateral edge of the breast to the chest wall. Marking out the lateral breast border before surgery with the patient standing up can be helpful as a guideline to ensure the dissection curves around the lateral edge of the breast rather than proceeding too far laterally, which can lead to injury of the anterior branches of the lateral intercostal nerves. Oftentimes with precise dissection, anterior branches can be seen running in the subcutaneous tissue from the lateral breast to the central breast/NAC and carefully preserved within that tissue as the mastectomy specimen is removed. The technique for NSM may vary based on the surgeon's preference. Typically, anterior or posterior breast dissection approaches are the most common. The identification of intercostal nerves (IC) may vary depending on the chosen approach. The following descriptions of these approaches are detailed below, with a step-by-step breakdown provided in Table 1.

Anterior Approach

This is our preferred approach. It can be used by surgeons who prefer to perform the breast anterior dissection first, followed by medial to lateral dissection. In

Table 1. Detailed Description of the Nerve-sparing Mastectomy and Neurotization Techniques

Breast Surgeon	Plastic Surgeon
1. Inferolateral incision is preferred. Two options for the identification of the IC nerves:	1. Identification of the lateral IC nerves 1–2 cm lateral to the pectoralis border
A: At the end of mastectomy dissection:	2. Uninjured nerves should be preserved
1. The breast is completely removed except for lateral dissection of the breast	3. Assess transected nerves for length and diameter
2. The breast is reflected laterally to reveal its undersurface	4. IC nerve dissection toward the chest wall by dividing the serratus and tracking the nerve to the rib border for extra length
3. Blunt dissection with a fine curved clamp is performed ~1–2 cm lateral to the edge of the pectoralis muscle to find the nerve(s)	5. If multiple nerves are available, they can be used as autografts
4. Once a nerve is identified, it is dissected for several centimeters into breast parenchyma to gain additional length. It is then sharply transected and left for the plastic surgeon.	6. 1–2 mm, 5 or 7 cm nerve allograft is sutured to the nerve stump using few 8-0 or 9-0 nylon epineural sutures
B: Early in the mastectomy dissection during posterior dissection:	7. 15 mm, 1–2 mm nerve conduit is secured to the epineuron with 8-0 nylon sutures to safeguard the anastomosis
1. During the posterior breast dissection, as the breast is lifted anteriorly with a retractor, the surgeon looks for the nerves just lateral to the edge of the pectoralis muscle	8. The breast reconstruction is completed as planned
2. Blunt dissection with a fine curved clamp is performed ~1–2 cm lateral to the edge of the pectoralis muscle to find the nerve(s)	9. Drains are placed superior and inferior to the implant before NAC neurotization
3. Once a nerve is identified, it is dissected for several centimeters into breast parenchyma to gain additional length. It is then sharply transected and left for plastic surgeon.	10. If distal nerve stump at the NAC: end-to-end anastomosis is done between the nerve graft and the distal stump with 9-0 nylon epineural sutures.
	11. If no distal stump: direct neurotization of the nipple is performed using 9-0 nylon epineural sutures.
	12. Mastectomy incision is closed as planned.
	13. Surgical bra is placed.

this case, after the anterior dissection is completed, the breast specimen is dissected off the pectoralis muscle and then reflected laterally to expose the undersurface of the breast. At this point, the surgeon can start searching for the intercostal nerves when the edge of the pectoralis muscle becomes visible. Blunt dissection with fine instruments allows the surgeon to carefully identify nerves while avoiding thermal injury. In cases of uncertainty regarding a potential nerve, gentle traction on the nerve will result in skin puckering where the terminal branches of the nerve are present. Once a nerve is identified, it can be dissected several centimeters into the breast parenchyma before branching too thin for allografting. The distal end of the nerve is then sharply transected, and the mastectomy proceeds as planned. [**See Video 1 (online)**, which displays a nerve-sparing mastectomy and neurotization of the NAC–anterior approach.]

It is imperative to handle nerves gently with fine instruments, such as a McAbe nerve dissector and bipolar or monopolar electrocautery on low settings. Forceps should not be used to grasp, pull, or clip the nerves, as it may cause permanent damage to their delicate structure. Moreover, the avoidance of bleeding is critical, as it can impede the identification of nerves. Given that intercostal nerves closely accompany vascular bundles, it is recommended to clip these vessels rather than cauterize them, as cauterization can hinder nerve visibility.

Posterior Approach

This approach can be used by surgeons who prefer to perform the lateral and posterior breast dissection first, followed by the dissection of the lateral breast border to access the axillary lymph nodes. After the incision, the surgeon starts the posterior breast dissection from the pectoralis fascia. Once the lateral breast border is reached, then it is advisable to look for the nerves approximately 1–2 cm lateral to the pectoralis border This can be accomplished by applying gentle upward traction to the breast tissue with a lighted retractor, causing the lateral breast border to tent and reveal the intercostal nerves (Fig. 3). An effective method for identifying these nerves is to follow the perforating vessels from the serratus to the breast tissue since the intercostal nerves run alongside these vessels. [**See Video 2 (online)**, which displays a nerve-sparing mastectomy and neurotization of the NAC–posterior approach.] Once the vascular bundle is isolated, the nerves can be clipped, isolated, and dissected off the breast tissue to provide extra nerve length, which is essential for the subsequent neurotization of the NAC. Once the fourth intercostal nerve (ICN) is localized, gentle tugging on the nerve can create a dimple in the skin along the lateral border of the NAC, aiding in the identification of the distal nerve stump at the NAC level. This maneuver is crucial for the plastic surgeon, who will perform the end-to-end nerve anastomosis. After identifying, dissecting, and separating the nerves from the breast tissue, the mastectomy proceeds as planned.

NAC Neurotization and Skin Neurotization

After the completion of the mastectomy, the plastic surgeon proceeds with the neurotization procedure. The transected nerves are assessed for length and diameter.

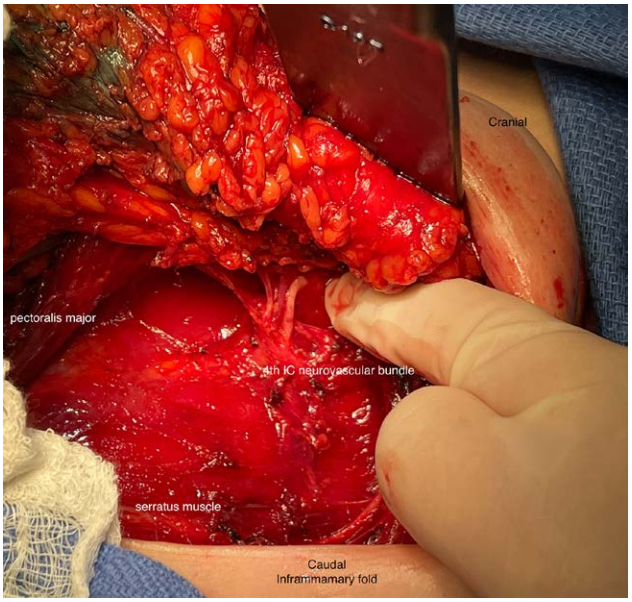

Fig. 3. Lateral fourth ICN tenting with the posterior dissection approach for the mastectomy.

Ideally, the selected intercostal nerve branches should measure at least 1–2 mm in diameter and offer sufficient length to reach the NAC without tension. To gain additional nerve length, the plastic surgeon may dissect the nerve toward the chest wall, dividing the overlying serratus muscle and tracking the nerve near the intercostal space. This maneuver can add up to 3–5 cm of length to the nerve stump, with an additional 10 minutes added to the surgical time. Once an adequate length is achieved, a 1–2 mm, 5 or 7 cm nerve allograft (Axogen) is sutured to the nerve stump using 8-0 or 9-0 nylon epineural sutures. To safeguard the neural anastomosis, a 15 mm, 1–2 mm nerve conduit (Axogen) is applied and secured in place with 8-0 nylon epineural sutures [**see Video 1 (online)**]. The nerve construct is gently pulled toward the lateral chest for subsequent suturing to the NAC at the end of the procedure. Care should be taken to avoid disrupting the construct during mesh or implant placement, particularly when using suction devices. If allografts are not available, another option is the dissection of a second intercostal nerve, which can be used as an autograft (Fig. 4).

Standard prepectoral or submuscular implant-based reconstruction, whether direct-to-implant or tissue expander-based, is conducted. Once breast reconstruction is complete, the nerve graft is positioned over the implant-mesh construct and directed to the undersurface of the NAC. If a distal nerve stump is identified, usually at the lateral border of the NAC, an end-to-end or end-to-side anastomosis is performed between the distal nerve and the nerve allograft using 9-0 nylon sutures. In cases where a distal nerve is not identified, direct neurotization of the NAC is pursued by connecting the nerve graft to the undersurface of the NAC skin. It is crucial to prevent tension on the grafted nerve, as excessive tension can disrupt the anastomosis. Drains should be positioned before the

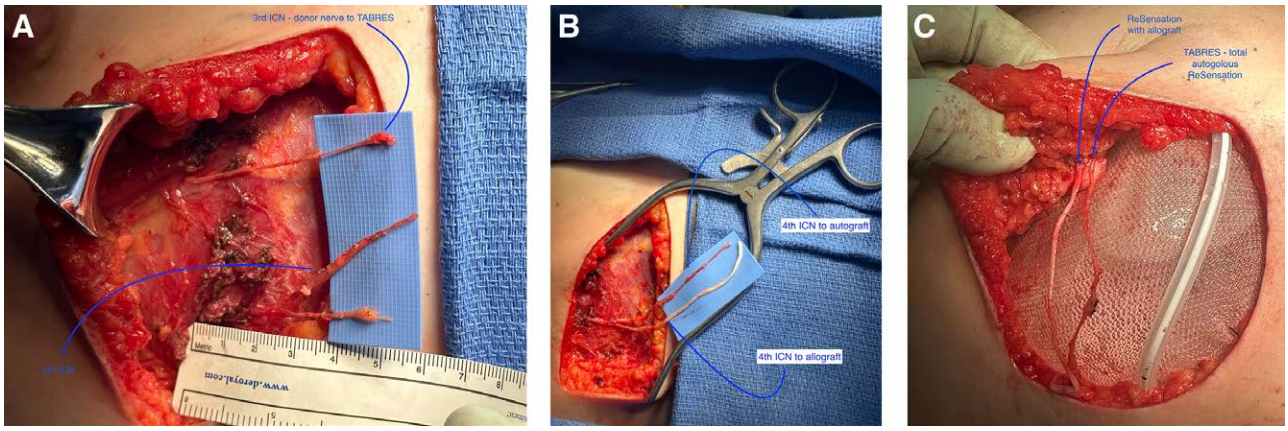

Fig. 4. NSM through an IMF approach and the disssected IC nerves. A, Third and fourth ICN dissected. B, The third ICN was divided and used a donor nerve to one branch of the fourth ICN for total autogenous breast neurotization (TABRES). The second fourth ICN branch was connected to a nerve allograft. C, Both distal ends were anastomosed to the NAC as a direct target.

Table 2. Postoperative Protocol for Nerve-sparing Mastectomy and Breast Neurotization

Preoperative	Postoperative Period				
	1–4 wk	4–6 wk	3 mo	6 mo	12 mo
Patient's education	Surgical bra Minimal arm abduction	Surgical bra Start PT/OT	Patient to resume all activities and exercise	f/u	f/u
Breast sensory testing using Semmes Weinstein monofilaments		Breast sensory testing	Breast sensory testing	Breast sensory testing	Breast sensory testing
BREAST-Q		BREAST-Q	BREAST-Q	BREAST-Q	BREAST-Q
Sensory rehabilitation protocol	Start rehab protocol within 1-wk postoperative	Breast rehab	Breast rehab		

NAC anastomosis, in a location that avoids any risk to the nerve graft.

Successful NAC neurotization necessitates specific conditions: effective collaboration between breast and plastic surgeons and a comprehensive understanding of the procedure's technical aspects, adequate nerve length without tension, a proper size match between the nerve graft and the recipient's nerve, and minimal tension at the nerve repair site to prevent fascicle "bunching." Short nerve stumps, poor technique, large implants, and devascularized mastectomy flaps predispose the procedure to failure, and it is advisable to consider aborting the neurotization procedure.

Our patient inclusion criteria for breast neurotization are broad, encompassing patients of all ages, breast sizes, and mastectomy types. For small- to moderate-sized breasts and careful dissection technique, neurotization and nerve-sparing mastectomy should be possible in more than 80% of your patients. Certain patients with large-volume breasts, broad-based breasts, or wide implants may not be suitable candidates for neurotization if adequate nerve length and tension-free nerve allografting cannot be achieved. Patients with multiple co-morbidities, previous radiation therapy, poor comprehension of the procedure, or those aged older than 65 and those who will undergo adjuvant chemotherapy and radiation should be informed that sensory recovery following neurotization may be less favorable due to impaired nerve growth. As no additional breast tissue is intentionally left behind as part of careful identification and preservation (when possible) of intercostal nerves, this approach can be safely offered to patients having both therapeutic and risk-reducing mastectomies. However, for patients with extensive lateral cancers/ductal carcinoma in situ, care should be taken to limit the extent of dissection of intercostal nerves into the breast parenchyma.

It is crucial to educate patients undergoing this procedure about what to expect post surgery (Table 2). Nerves regenerate at a slow rate, approximately 1 mm per day, typically starting about 4 weeks after the procedure. Full sensory recovery may take several months to years. Any sensation noted within the first 3 months is likely due to nerve preservation during the mastectomy. During sensory recovery, patients may experience abnormal sensations such as "pins and needles" and occasional sharp pains. We recommend initiating a "desensitization" and sensory reeducation protocol approximately 4 weeks after surgery.

Next Steps

The goal of nerve-sparing mastectomy and NAC neurotization is to reestablish both protective and erogenous sensations—a challenging but highly desirable achievement in breast reconstruction. Although numerous

Table 3. ICD-10 and Current Procedural Terminology (CPT) Codes Used in Breast Neurotization

ICD-10-CM* code	R20.1 Anesthesia of the skin R20.1 Hypesthesia of the skin
CPT† code	Nerve repair
64910	Nerve repair, with synthetic conduit or vein allograft
64912	Nerve repair, with nerve repair, each nerve, first strand
+64913	Nerve repair, with nerve allograft, each additional strand (list separately in addition to primary code)
64722	Exploration, neurolysis, or nerve decompression

*2023 ICD-10-CM, www.cms.gov.
†CPT 2023 Professional Edition (AMA).

publications have reported improved outcomes with breast neurotization, results can vary due to differences in techniques.[1–12,18,19] The combination of nerve-sparing mastectomy and breast neurotization with autografts or allografts may enhance sensory recovery in the breast. For reliable evaluation of outcomes, standardization of nerve-sparing mastectomy and NAC neurotization techniques is essential. Additionally, the standardization of preoperative and postoperative sensory testing protocols and patient-reported outcomes is critical to validate these procedures. Multicentric registries or clinical trials will play a pivotal role in determining the time required to achieve peak sensory recovery and the benefits of sensory rehabilitation programs.

Limitations

One notable limitation is the absence of a specific Current Procedural Terminology code for breast neurotization. Currently, commonly used codes are listed in Table 3. To avoid insurance denials, the diagnosis code for skin hypesthesia should be applied at the time of surgery. Some insurance providers consider breast neurotization experimental, which may necessitate a "peer-to-peer" discussion for approval. We hope that this status will change as long-term results and quality-of-life studies are published. Presently, patients may be offered an out-of-pocket cost to cover nerve grafts and conduits if insurance denies the procedure.

The cost of nerve allografts is substantial, so we recommend proceeding with neurotization only under favorable conditions, such as when there is a shorter nerve gap, a sizable intercostal nerve, and no tension at the repair site. Failure to observe these principles increases the risk of procedure failure, which can be disappointing for both the surgeon and the patient.

Neurotization and tissue expansion present a contentious issue in surgical practice. Typically, it is recommended to wait 3–4 weeks for nerve healing before initiating tissue expansion. This delay is crucial as stress at the suture line can disrupt anastomosis, potentially impacting reinnervation. Thus, we advocate for fully expanding the tissue expander during surgery to determine the total nerve length needed and to minimize the need for postoperative expansions. Expansion itself should commence 3–4 weeks postsurgery at a slow rate, with patients informed of the risk of procedure failure during in-office expansion.

For patients undergoing radiation therapy (RTX) after mastectomy, our protocol adjusts accordingly. Because RTX usually starts between 3 and 12 weeks postsurgery, we aimed to achieve near-optimal expansion volume during the surgical procedure to accommodate the treatment timeline. However, expedited expansion due to early RTX initiation poses challenges to optimal neurotization. Patients should be made aware of the increased risk of neurotization failure associated with fast expansion in such cases.

Although our standard protocol involves a 4-week waiting period for slow expansion, we tailored our approach to align with the timing of RTX, ensuring the best possible outcome for each patient. Nonetheless, the lack of literature on the optimal timing for expansion post neurotization underscores the need for future research in this area.

CONCLUSIONS

Breast neurotization remains a developing technique and is not widely offered (or performed) at most centers specializing in breast cancer treatment. To establish its validity and study its potential benefits, a larger number of patients, clinical trials, and long-term data are needed. We hope that by familiarizing breast and reconstructive surgeons with this procedure, we can gain momentum in our research efforts and ultimately enhance the care provided to mastectomy patients.

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DISCLOSURES

Drs. Moreira and Keleher are consultants of Axogen Inc. Dr. Gomez is a consultant of Mammotome. Dr. Peled is a consultant of Axogen Inc., Allergan/Abbvie, and Sientra.

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