Review Article on New Frontiers in Breast Reconstruction

Post-mastectomy sensory recovery and restoration

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Abstract: Breast sensation has recently become an integral aspect of the reconstructive goal after mastectomy and is an important consideration for many patients. Neurotization techniques using primary coaptation, autograft, allograft, or nerve conduit have been used for autologous flaps, such as the deep inferior epigastric perforator (DIEP) flap. Outcomes have shown improved sensation and faster sensory recovery in the flap skin in immediate neurotized DIEP flap breast reconstructions compared to delayed reconstruction. Breast flap neurotization during reconstruction is a rapid and simple procedure with minimal morbidity. An improved understanding of breast anatomy and innovative modifications to breast reconstruction have made the restoration of breast sensation achievable, and promising results have been obtained with respect to sensory return and patient satisfaction.

Keywords: Breast reconstruction; breast flaps; autologous-based reconstruction; neurotization; sensory recovery; post-mastectomy sensation

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Introduction

Breast cancer is exceedingly common; one in eight American women will develop breast cancer over the course of their lifetimes. However, breast cancer mortality rates have also dropped by over a third since 1990 thanks to early detection and evolving treatment modalities (1). With this increase in the survival rate, breast reconstruction has become increasingly common. Indeed, over 100,000 breast reconstructions were performed in the United States in 2016 (2). This trend is encouraging, given the significant psychosocial benefits of breast reconstruction established in the literature (3). The presence of breast sensation, in particular, is linked to increased patient satisfaction following reconstruction (4).

The two main types of breast reconstruction are autologous reconstruction, which uses the patient's own tissue, and implant-based reconstruction. Deep inferior epigastric perforator (DIEP) flap reconstruction, which uses excess tissue from the lower abdomen, remains the gold standard in autologous breast reconstruction. It is popular for its natural appearance and feel, its long-term aesthetic result, and general patient satisfaction (5,6). Over the past two decades, the focus has shifted from the microsurgical success of the DIEP flap to improving the aesthetics of the reconstructed breast and the abdominal donor site, and outcomes approaching those of aesthetic plastic surgery have been achieved in many cases. Less attention has been paid to functional restoration, namely, the restoration of sensation to the mastectomy skin following oncologic surgery and subsequent reconstruction.

Following a mastectomy, women suffer the loss of a key physical component of femininity and sexuality from both a visual and sensory perspective. Many women are not advised about the sensory deficits they will encounter following surgery, which can range from diminished to absent sensation and which can be debilitating for some

patients. In addition, the lack of protective sensation can pose serious problems; patients have been known to suffer thermal injuries from common household items due to breast numbness (7,8). Preserving and restoring post-mastectomy breast sensation has thus become the latest frontier in breast reconstruction.

Surgical anatomy and technique

The nipple-areolar complex is innervated primarily by the third, fourth, and fifth intercostal nerves, and the remainder of the breast also includes innervation from the second and sixth intercostal nerves and the supraclavicular nerves (9). The intercostal nerves give off lateral and anterior cutaneous branches. The lateral branches are sacrificed during a mastectomy as they enter the gland in the deep plane and then provide sensory branches to the skin. The anterior branches travel in the subcutaneous plane and can, therefore, sometimes be spared during a nipple-sparing mastectomy, which can help preserve sensation in the mastectomy skin regardless of the type of reconstructive surgery the patient might subsequently undergo.

In autologous reconstruction, either the anterior or lateral branches of the intercostal nerves, which are severed during the mastectomy, can be used as the recipient nerves. The recipient nerve of choice is the anterior branch of the third intercostal nerve, which arises medially in the intercostal space, slightly inferior to the third rib and medial to the sternum. This nerve is ideally situated as it lies in the same operative field as the vascular anastomoses for the flap. To maximize the length of the recipient nerve, it is dissected along the course it travels with the pectoral intercostal perforator to innervate the breast skin (10).

As the DIEP flap is the most commonly used flap in autologous breast reconstruction, the neuroanatomy of available donor nerves in the abdomen is relevant. In an anatomical study, Mori *et al.* demonstrated that the anterior cutaneous branches on the tenth, eleventh, and twelfth intercostal nerves, which enter the rectus abdominus flap slightly superior to the skin paddle in question, ought to be innervated to maximize flap sensation after innervation. The appropriate nerves for coaptation are found in the inferior half of the flap (11). The sensory components of the intercostal nerves pierce the rectus abdominus and follow the same course as the perforating vessels to innervate the abdominal skin. When one of these nerves is identified at the level of the fascia, it can be dissected below the fascia for additional few centimeters to allow for easier coaptation to the chest intercostals. Dissection ceases at the point where the sensory component meets with the motor contribution of the nerve to avoid harvesting unnecessary motor nerves, to preserve the neuro-integrity of the abdominal wall, and to avoid abdominal bulges.

Nerve coaptation can then be performed using autografts, allografts, or nerve conduit tubes, depending on the gap. As with any nerve repair, the goal is a tension-free repair. In the peripheral nerve literature, a primary nerve repair is preferred as it yields the best outcomes, but this has not been clearly delineated in the breast reconstruction literature. If there is a gap between the recipient and donor nerves, coaptation can be achieved with a nerve autograft, which can be harvested from another donor nerve from the flap, usually up to 3 cm in length. Most of the lower perforators, which are rarely used for flap perfusion, have an accompanying nerve that may be used as an autograft. If autograft is unavailable, a nerve allograft is also an option. Finally, a gap of up to 3 cm can be addressed with a nerve conduit, although the nerve repair literature generally suggests these gaps be limited to 5–10 mm if possible for best outcomes (12-14).

Some alternative flaps for breast reconstruction have sensory donor nerves which can be coapted. The profunda artery perforator and transverse upper gracilis flaps include a sensory branch of the femoral nerve. The superior and inferior gluteal perforator flaps include the superior and inferior gluteal nerves, respectively, for sensation. The lateral thigh perforator flap includes a branch of the lateral femoral cutaneous nerve. All of these sensory nerves are options for sensory nerve coaptation in autologous breast reconstruction. Cornelissen *et al.* demonstrated that while the innervated DIEP flap becomes more sensitive to pressure over time compared to a healthy native breast, the profunda artery perforator flap, lateral thigh perforator flap, superior gluteal artery flap, and transverse upper gracilis flap all demonstrate less sensitivity to monofilament pressure compared to a healthy breast (15).

Natural history of post-mastectomy sensory recovery

Debate relating to the recovery of sensation in post-mastectomy skin after flap reconstruction dates back to the 1990s and stems from the argument that the skin recovers sensation regardless of flap neurotization (16,17). In 1999, Blondeel *et al.* noted that while some sensation was found to return to skin flaps that were not innervated, flaps that

had undergone neurotization were found to have earlier spontaneous recovery of sensation and higher-quality sensation and were more likely to have erogenous sensation restored (18). Several subsequent studies subsequently have obtained similar results, showing that while some sensation may recover spontaneously, neurotizing an underlying autologous flap or using a sensate flap yields better results (19-21). The topic has become increasingly less controversial with the advent of advanced technologies that can characterize sensation in relation to numerical pressure readings, such as pressure-specified sensory devices (PSSD) (22). A common criticism of the traditional Semmes-Weinstein monofilament test lies in its user-dependence and its consequent potential unreliability. However, the use of devices such as the PSSD, has partially ameliorated this concern.

In a retrospective study by the senior author of this paper, neurotization of the DIEP flap using the third anterior intercostal nerves resulted in significantly improved sensory recovery in the flap skin, which was even greater than that in the native mastectomy skin. Sensory return was found to be greater in immediate reconstructions than in delayed reconstructions. Furthermore, sensation recovered in DIEP flaps neurotized using a nerve conduit was significantly better than in corresponding areas of the DIEP flaps neurotized by direct coaptation. This observation suggests that using a nerve conduit with a small gap may allow the fascicles to align appropriately between the two ends of the nerve (23).

Conclusions

The restoration of sensation to mastectomy skin is a key component of the breast reconstruction process. Efforts should be made to preserve sensory nerves as much as oncologically possible during the mastectomy and to restore sensation through nerve coaptation during autologous breast reconstruction. Breast flap neurotization during reconstruction is a simple and fast procedure that does not contribute to morbidity. Given the evolving body of literature demonstrating improvements in sensory recovery and patient satisfaction following neurotization and nerve preservation, efforts should always be made to preserve and restore sensation in the reconstructed breast where possible.

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