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SPECIAL TOPIC
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Frontiers in Oncologic Reconstruction

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Objectives: The authors seek to highlight some of the ongoing challenges related to complex oncologic reconstruction and the current solutions to these problems. **Summary:** The standard of care in reconstruction following oncologic resection is continually evolving. Current frontiers in breast reconstruction include addressing animation deformity through prepectoral reconstruction, offering autologous reconstruction to patients with limited donor sites, and improving postoperative sensation with innervation of free tissue transfer. Facial nerve reconstruction and contour defects pose an ongoing challenge in patients undergoing parotidectomy requiring complex nerve transfers and autologous reconstruction. Lymphedema is not a monolithic disease, and as our understanding of the pathophysiology improves, our surgical algorithms continue to evolve. *(Plast Reconstr Surg Glob Open 2019;7:e2181; doi: 10.1097/GOX.0000000000002181; Published online 12 June 2019.)*

INTRODUCTION

The advent of free tissue transfer has revolutionized complex reconstruction, allowing surgeons to replace like with like. Historically, surgeons would often employ the reconstructive ladder, a concept proposed by Mathes and Nahai[1] that offers a stepwise framework for wound closure. Improvement in microsurgical technique, however, has expanded the scope of free tissue transfer, necessitating refinement of the conventional reconstructive ladder. Gottlieb and Krieger[2] have since introduced the reconstructive elevator, which allows for flexibility in choice of reconstructive technique to better match clinical indication, despite surgical complexity.

Standard of care in reconstruction following tumor ablation is continually evolving. One of the most exciting challenges plastic surgeons face is to develop new solutions that elevate the standard. The topics in this paper are a small cross section of some devastating problems that patients face following cancer treatment. These include lymphedema, facial paralysis following parotidectomy, loss of sensation following mastectomy, and animation deformity following subpectoral prosthetic reconstruction. The following is a review of some potential solutions to these vexing issues.

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FRONTIERS IN BREAST RECONSTRUCTION

Prepectoral Breast Reconstruction and Animation Deformity

Animation deformity can be problematic in some patients undergoing subpectoral or submuscular breast reconstruction, particularly those who are very active.[3–5] However, subpectoral placement provides the benefit of additional soft tissue coverage to address the complications of exposure and capsular contracture seen in the earliest forms of breast reconstruction which were prepectoral. The subsequent introduction of acellular dermis and near-infrared imaging have increased the reliability of prepectoral techniques. Coverage of the prosthesis with acellular dermis may minimize capsular contracture, and near-infrared imaging may improve predictability in mastectomy flap perfusion, making prepectoral placement a viable option.[6–8] Provided that the perfusion to the mastectomy skin is adequate, prepectoral reconstruction offers patients a viable alternative and avoids potential morbidity and pain of muscle dissection and expansion. Patients generally require fat grafting to compensate for the absence of muscle coverage in the upper pole. Sbitany has cited a number of considerations when selecting patients such as history of radiation status, oncologic status, and a critical intraoperative assessment of mastectomy skin flap viability.[9–12] Additional studies, preferably randomized to minimize selection bias, would be valuable in determining the overall cosmetic outcome and satisfaction of patients undergoing prepectoral versus subpectoral for informed consent.

Autologous Reconstruction in the Thin Patient

Patients typically choose autologous reconstruction for a natural, lifelong, and maintenance-free result.[13,14] However, some patients may not be seen as candidates because they

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are thin or do not have a traditionally favorable abdominal donor site. In patients who are marginal candidates, limited donor tissue may result in an unfavorable result with lack of projection and contour irregularity.[15]

Similarly, patients with an inadequate abdominal donor site, but who are seeking an autologous only reconstruction, may be candidates for a lower extremity-based flap.[16] Allen et al.[17] published their experience with the profunda artery perforator flap in 2012, and because then this flap has widely been adopted as an acceptable alternative for breast reconstruction. Similarly, the diagonal upper gracilis flap provides an excellent alternative to the abdomen in patients seeking autologous reconstruction (Fig. 1). With its increased width, the flap allows for improved contour of the reconstructed breast. Moreover, the orientation of the flap's donor site minimizes the risk of lymphedema and optimizes wound healing along the lines of least tension.[18] The lateral thigh perforator flap is another option in carefully selected patients that allows for soft, pliable tissue to reconstruct the breast.[19] While requiring a more visible donor site scar, the lateral thigh perforator flap allows for a 2-team approach and also avoids the lymphatics of the lower extremity.

Another option for patients with a paucity of donor tissue is the combined use of autologous and implant-based reconstruction, or hybrid reconstruction.[19,20] Although hybrid breast reconstruction offers the benefits of both autologous and prosthetic reconstruction, it also comes with the disadvantages of both procedures. Acceptable complication rates have been reported with favorable esthetic results, suggesting that the combination of implant and free flap safely improves projection, while maintaining the natural contour of the breast mound.

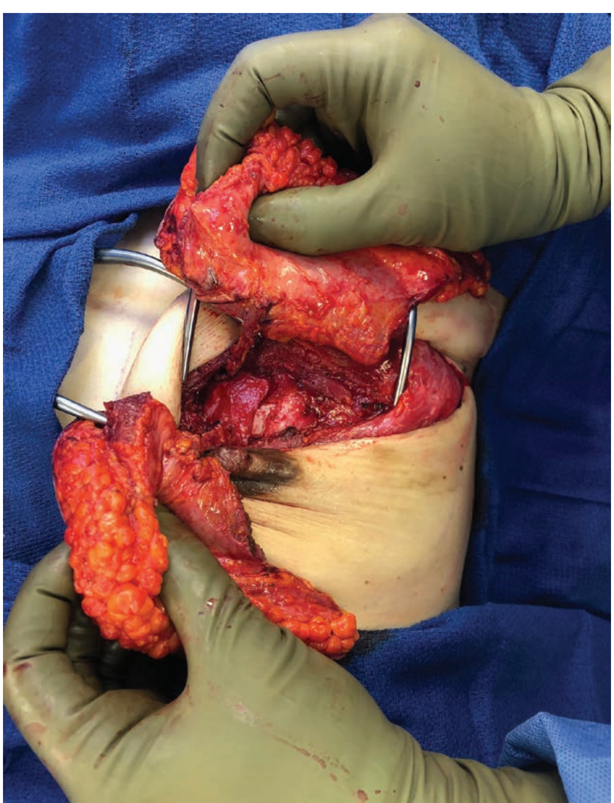

Fig. 1. Stacked diagonal upper gracilis flaps for autologous breast reconstruction.

Between the innovations of lower extremity-based flaps and the technical advances in stacking free flaps, fat grafting, or combining autologous reconstruction with prosthetic devices, the reconstructive surgeon now has many tools for providing an esthetically pleasing and safe outcome for patients who had historically not been considered candidates for autologous reconstruction.

Sensation in Autologous Breast Reconstruction

Loss of sensation following mastectomy remains a significant problem for patients undergoing breast reconstruction, so much so that it caught the media's attention in a *New York Times* piece in 2017.[21–23] BREAST-Q data by Pusic has shown that patients are bothered by loss of sensation and that anterior chest hypesthesia is a significant reminder of their oncologic past. It has been widely reported that improvement in breast sensation correlates with patient satisfaction.[24] Addressing this issue has become the final frontier in comprehensive breast reconstruction.

A number of breast neurotization techniques have been developed to restore sensation to the breast following microsurgical free flap transfer, including direct nerve coaptation or use of nerve conduit.[25] Importantly, innervated autologous flaps consistently outperformed their noninnervated counterparts in postoperative sensory recovery.[26–28] Although many surgeons perform a single-nerve coaptation of cutaneous sensory fibers and adjacent recipient nerves with restoration of nearly 50% of baseline breast sensation,[29] Puonti et al. recently described a dual neurorrhaphy technique for breast sensitization with improved tactile sensation and temperature discrimination.[30]

However, variability in technique and limited number of prospective, randomized controlled trials has limited the acceptance of a standardized neurotization methodology. Furthermore, recent studies have focused on *objective* clinical assessment of nerve sensation to validate breast neurotization following microsurgery or guide clinical practice with regard to spontaneous reinnervation.[31] Having focused mainly on Semmes Weinstein and caloric metrics, the current literature does not necessarily assess *subjective* sensation in meaningful patient-reported outcomes. Larger studies with patient-reported outcomes are warranted to better assess sensation following neurotization, including the relative advantage of using medial or lateral intercostal nerves as a donor or harvesting of multiple nerve levels. The senior author favors using the lateral T4 intercostal nerve or and additional T3 level (Fig. 2). This avoids denervating potentially intact medial branches and is the dominant nerve responsible for sensation to the nipple areola complex.

FRONTIERS IN FACIAL RECONSTRUCTION

Facial Nerve Reconstruction and Contour Deformity in Parotidectomy Defects

Management of head and neck tumors often involves surgical resection of the parotid gland, which can result in

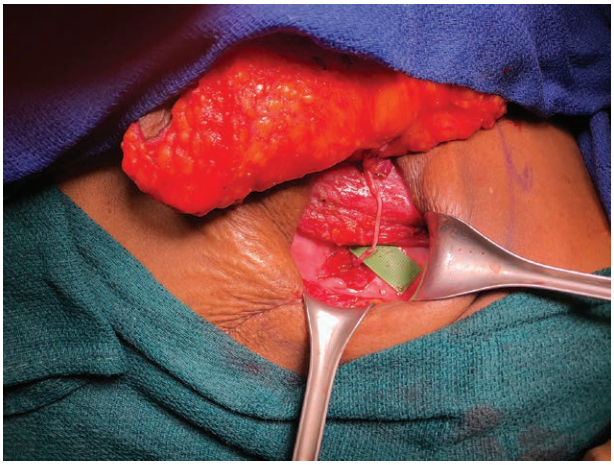

Fig. 2. Innervation of autologous breast reconstruction using the lateral T4 intercostal nerve.

facial paralysis, volume loss, and synkinesis. In particular, paralysis of the eye is a significant issue in terms of quality of life. Challenges in addressing facial nerve reconstruction can include the lack of a usable or reliable proximal facial nerve stump, likely due to positive microscopic disease in proximal stump or history of mastoidectomy and temporal bone resection with a protracted distance between the proximal and distal stumps. The resulting facial paralysis can have profound effects on the psychosocial well-being of the patient. Although eye closure is a priority, historically neurologic reconstruction has targeted improvements in smile with static procedures including lid weight and tarsorrhaphy or canthoplasty to address the eyelid.

Using multiple targeted nerve donors may increase the likelihood of meaningful facial motion and reduce the level of synkinesis. Dual nerve transfers with nerve to masseter and minihypoglossal was first described by Dayan et al[32] in cases where the use of proximal facial nerve stump was unreliable (Fig. 3). This technique can also be supplemented with primary facial nerve repair and grafting in patients presenting with preexisting paralysis who may not have a reliable result from a nerve graft alone. Restoration of eye sphincter function is reliably improved by nerve transfer.

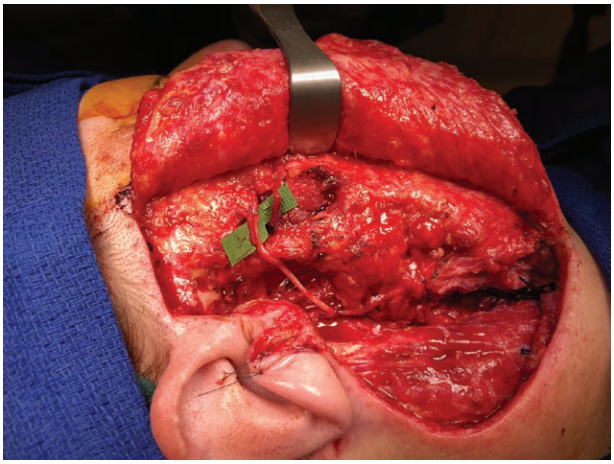

Fig. 3. Facial nerve reconstruction using dual innervation technique.

Furthermore, recent advances in free tissue transfer have facilitated correction of periauricular defects. The use of an anterolateral thigh flap in combination with masseteric nerve transfer has been described by Cristóbal et al[33] in a case series of 6 patients to improve contour deformity and facial nerve function. The authors observed adequate volume replacement and restored facial symmetry, with no partial or total flap loss. Additionally, masseteric nerve coaptation to the buccal branch of the facial nerve was associated with improved facial reanimation, which, coupled with anterolateral thigh flap-based volume replacement, conferred superior esthetic and functional outcome following restoration of periauricular defect (Fig. 4).

FRONTIERS IN LYMPHATIC RECONSTRUCTION

Improving Our Understanding of Lymphedema

Plastic surgeons have tackled this puzzling and disabling disease for decades with significant progress in treating patients who otherwise have little hope for improvement. Lymphatic surgery in its dawn was largely applied to anyone having a swollen extremity with limited understanding of the pathophysiology of the disease itself.

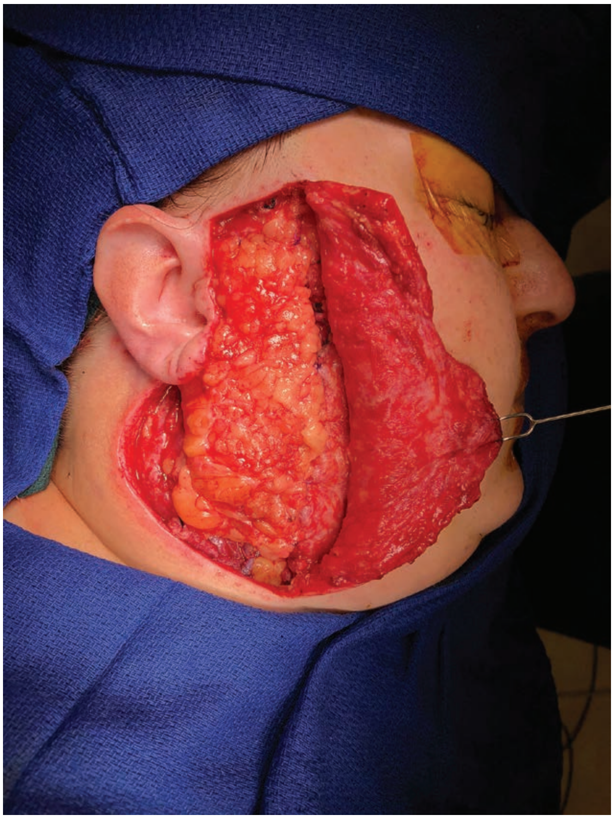

Fig. 4. Adipofascial anterolateral thigh flap for improving contour following parotidectomy defect.

Advances in lymphatic imaging and basic science research have resulted in the evolution of patient selection, operative techniques, and outcomes. For example, the size of the limb itself is now recognized to be a limited outcome, as the composition in terms of fat deposition and fluid accumulation varies significantly among patients. Assessment of lymphatic function by near-infrared fluorescence lymphangiography is now commonplace and allows one to determine the likelihood of identifying adequate lymphatic vessels for bypass. We have also collectively learned to appreciate the importance of the venous outflow in cases where the axillary or femoral veins may be severely compromised. Venous drainage is a paramount consideration in the assessment of a patient for possible lymphovenous bypass or even vascularized lymph node transfer.

Moreover, in the backdrop of the snapshot of patient evaluation lies the unrelenting immunologic process that leads to progressive disease. Basic questions remain unanswered such as does surgery arrest this process or provide symptomatic relief? Advances in targeted medical therapies aimed at blocking specific parts of the inflammatory process that are responsible for lymphedema will hopefully lead to a drug that can stop this progression and possibly reverse it. For example, Mehrara has shown that topical tacrolimus prevents the development of lymphedema in animal studies.[34] Similarly, Rockson has shown that ketoprofen, a nonsteroidal anti-inflammatory drug (NSAID), has functioned as a targeted anti-inflammatory with some success in treating lymphedema in placebo-controlled trials.[35] We believe that the most likely solution may be a combination of surgery to provide a physical means of fluid egress from the limb and an adjuvant medical therapy to block the immunologic pathology causing fibrosis and lymph stasis.

Lymphedema is not a monolithic disease, and there are differences among patients, which are not appreciated using current staging systems, which are solely based on physical exam. A better understanding of this disease process is essential to determine when surgery is indicated. Only once we have appropriately quantified the differences in these patients can we best comprehend how to best execute surgical reconstruction and maximize our outcomes. In summary, the lymphatic surgeon needs to evaluate the patient's edematous limb for fluid versus fat composition, asses lymphatic function through imaging, determine venous drainage status and availability, and potentially conclude the patient's immunologic status.

Evolution of Treatment Algorithms Results in Improved Outcomes

Lymphatic surgeons have typically championed one procedure over another within lymph node transfer versus lymphatic bypass versus liposuction. However, we submit that no one procedure reigns supreme. Liposuction, for example, was highly controversial and infrequently used in lymphedema. We now know that in patients who have a fat dominant limb and are fully compliant with compression are appropriate candidates for this procedure.[36] Consequently, although liposuction was previously avoided in the microsurgical community, it has now become a reliable and common tool for most lymphatic surgeons when tackling the fat component of the limb. Therefore, the authors feel that the appropriate question is not which procedure is best but rather which procedure is most appropriate for which patient.

In general, it appears that for lymphatic bypass to be most successful, one needs (1) patent and ideally functional lymphatics to bypass and (2) a venous system that is not compromised. These qualifications tend to be present in patients with earlier lymphatic disease as opposed to late presentation. Thanks to the work of Koshima, lymphaticovenous anastamosis (LVA) has had a resurgence using supermicrosurgical technique where venous pressures in the capillary bed are low-pressure systems.[37,38] Improved instrumentation and surgical techniques have led to improved results.[39]

Vascularized lymph node transplant, in contrast, does not rely on patent lymphatic vessels, although it remains to be seen if the best candidates are also patients with early disease. Vascularized lymph node transfer (VLNT) involves transplanting an immunologic organ containing Vascular endothelial growth factor-C (VEGF-C), inducing lymphangiogenesis into the nodes.[40,41] Initial concerns about VLNT centered around the devastating potential for donor site lymphedema. Reverse lymphatic mapping was developed to maximize safety of this procedure and involves identification of critical nodes draining the limbs which are avoided during surgery.[42] Alternatives including supraclavicular lymph node harvest have significantly reduced this risk.[43] More recently, vascularized omentum lymphatic transplant and mesenteric node transfer have eliminated the risk of donor site lymphedema.[44,45] The omentum also provides a large surface area that may be beneficial in certain cases and can be split into 2 flaps, one placed proximally and one distally (Fig. 5).[46] Further insights into recipient vein selection and double venous drainage of the omentum focus on reducing venous pressure within the flap and providing physiologically favorable gradient for lymph egress.

Fig. 5. Dual-level transfer of vascularized omentum lymphatic transplant for management of upper extremity lymphedema.

The ultimate goal in lymphatic surgery would be to prevent lymphedema from occurring in the first place. Lymphatic reconstruction at the time of lymphadenectomy has gained popularity as patients with newly diagnosed breast cancer have become more aware of the disabling consequences of lymphedema. Prophylactic LVA ("LYMPHA") first described by Boccardo is an application of proximal lymphovenous bypass previously described by Campisi.[47,48] Early results from this approach are promising and close collaboration with the breast surgeons may further refine lymphadenectomy technique to reduce morbidity.[49,50] The field of immediate lymphatic reconstruction including prophylactic lymph node transfer is an area in need of more prospective controlled studies. If the risk of lymphedema can be significantly reduced many potential patients would avoid an incurable and progressive condition.

CONCLUSIONS

Advances in oncologic and microsurgical reconstruction have provided us with tools to solve many difficult problems patients face after surviving cancer treatment. High-level outcome studies evaluating the application of these techniques and technologies will further improve our understanding of which patients are best suited for a particular approach.

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