Strategies for Prevention and Management of Postoperative Wounds and Scars Following Microsurgical Breast Reconstruction: An Evidence-Based Review

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GENERAL PURPOSE: To provide an evidence-based review of strategies for the prevention and management of wounds and postoperative scars following microsurgical autologous breast reconstruction.

TARGET AUDIENCE: This continuing education activity is intended for physicians, physician assistants, nurse practitioners, and registered nurses with an interest in skin and wound care.

LEARNING OBJECTIVES/OUTCOMES: After participating in this educational activity, the participant will: 1. Identify operative considerations to promote wound healing in microsurgical autologous breast reconstruction. 2. Synthesize management strategies for major flap complications following microsurgical autologous breast reconstruction. 3. Explain features in the assessment, prevention, and treatment of scars following microsurgical autologous breast reconstruction.

ABSTRACT: Postoperative wound complications and unsightly scars have the potential to plague even the most elegant reconstructions performed by experienced surgeons. For patients undergoing autologous breast reconstruction, the risks of such outcomes may be increased, and so too are the oncologic and psychosocial consequences of prolonged reconstruction and increased scar burden. Strategies and products reported to aid in the prevention and management of such complications are abundant in the literature. In addition to a thorough preoperative assessment and optimization, the careful planning of incisions, flap design, and postoperative mobilization protocols may all aid in risk reduction. Prompt diagnosis and treatment of wound complications with various regimens, ranging from simple dressing changes to adjunctive technologies such as hyperbaric oxygen therapy, are critical. Obtaining an optimal scar appearance relies initially on a robust, tension-free closure. Postoperative dressings, ointments, injections, lasers, and other interventions have been used in a variety of settings with expectedly varied results. As such, this article aims to provide an evidence-based review of strategies for the prevention and management of wounds and postoperative scars following microsurgical autologous breast reconstruction.

KEYWORDS: microsurgical breast reconstruction, patient safety, postoperative complication, scar, wound

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INTRODUCTION

Autologous reconstruction of the postmastectomy breast may present an array of challenges for both patients and plastic surgeons. Postoperative wound complications often yield aesthetic deformity, ultimately leading to higher rates of elective revision surgery and lower patient satisfaction scores.[1] Arguably more importantly, complications may delay a patient's transition to the next stage of their cancer therapy. As a result, careful preoperative planning, risk stratification, medical optimization, and, when necessary, prompt treatment of complications are essential components of care. Recreating an aesthetic breast with minimal recipient and donor site scar burden is a parallel goal that often extends beyond the index reconstruction and has a direct impact on psychosocial well-being.[2]

To mitigate postoperative complications, potential risk factors for delayed wound healing should be explored in the preoperative consultation. A thorough patient history should include review of comorbid conditions (eg, diabetes, obesity), smoking history, and medication use (eg, systemic corticosteroids and other immunosuppressants). Prior and anticipated oncologic treatments with chemotherapy and/or radiation should be considered, because these may affect the timing of definitive breast reconstruction. Patients should be specifically counseled on the risk of wound complications based on their individual history. Modifiable risk factors should be addressed preoperatively, ensuring that patients are medically and nutritionally optimized prior to surgery. Importantly, reconstructive surgeons must work collaboratively with primary care providers as well as surgical, medical, and radiation oncologists to ensure that optimization does not lead to delays in oncologic treatment.

Intraoperative diligence and meticulous surgical technique are needed to identify and address potential sources of complications. During immediate breast reconstruction, for example, intraoperative indocyanine green angiography may help delineate regions at risk for mastectomy skin flap necrosis (MSFN), which may subsequently inform intraoperative decision-making. Anticipation of postsurgical complications may guide perioperative decision-making regarding adjunctive modalities to mitigate risk for delayed wound healing. Many donor sites are available for breast reconstruction, and flap selection should be informed by patient-related factors and tolerance for donor-site-associated morbidity.

Surgeons should likewise inquire about personal or familial history of hypertrophic scarring or keloid formation. Mechanisms and available options for managing scar burden should be discussed

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preoperatively, including the rough timeline for wound healing and scar maturation to appropriately set patient expectations. Assessment of existing postsurgical scars may be beneficial in determining a threshold for intervening on unsightly scars postoperatively.

A substantial amount of literature has been published on wound prevention and management strategies. Similarly, there are a multitude of products reported to reduce postoperative scar appearance. However, the pathophysiology of wound and scar formation and their respective therapies will vary based on the region of the body and the precise etiology. Whereas foundational tenets of wound care and scar management remain true, this article aims to review evidence-based strategies and products and highlight nuances as they affect autologous breast reconstruction.

WOUNDS

Operative Considerations

Although the specific biologic basis of wound formation and healing is beyond the scope of this review, it is important to understand the unique factors that adversely affect wound healing and how these apply in a clinical setting. As previously mentioned, determining the clinically relevant factors that might adversely affect wound healing begins with a thorough preoperative risk assessment. Surgical history and prior scars are of particular importance when planning abdominally based free-flap reconstruction, because potential variations in perforator anatomy and venous drainage patterns may impact both flap and donor site healing. The Pfannenstiel scar, for example, may induce physiologic changes analogous to flap delay, with resulting increases in perforator number and caliber, and improved venous drainage through the deep system.[3] Although excellent flap survival rates can be achieved with the aid of preoperative perforator mapping and meticulous flap design, the presence of scars does appear to increase the risk of donor site wound complications.[4]

Another important perioperative consideration is the type of mastectomy incision. Salibian et al[5] analyzed outcomes following nipple-sparing mastectomy with immediate autologous breast reconstruction and found that inframammary and inverted-T incisions portend an increased risk of ischemic complications within the mastectomy skin flap.[5] Tevlin et al[6] identified a similar risk profile, with inframammary and periareolar incisions correlating with increased rates of MSFN and nipple-areolar complex (NAC) necrosis, respectively.

Although alternative incisions, such as the radial, vertical radial, and lateral radial, have demonstrated lower rates of ischemic skin envelope complications, they might not always be feasible. For instance, patients with significant ptosis or macromastia often require reduction of the breast skin envelope to achieve an aesthetic result. In prophylactic cases, this is best achieved with staged reduction prior to mastectomy. Although a staged approach relegates the patient to two anesthetic events, it enables a reduction in the skin envelope, NAC repositioning, and improved vascularity of the mastectomy skin by way of flap delay. In retrospective studies, patients undergoing staged reduction were found to have lower rates of MSFN when compared with those undergoing single-stage mastectomies with similar weights.[7]

Oncologic mastectomy precludes a staged approach, and, therefore, skin reduction must be accomplished via direct excision. Both Wise pattern and vertical reduction mastectomy techniques have been described. Although randomized control trials (RCTs) are lacking, retrospective studies suggest that Wise pattern incisions carry an increased risk of mastectomy flap necrosis compared with vertical reduction.[8] Despite this data, Wise pattern mastectomy does allow for a more significant skin reduction and may sometimes be necessary. In a Wise pattern incision, breast skin is removed both horizontally and vertically and shaped conically to treat ptosis, leaving the patient with an anchor scar.[9] Meanwhile, in a vertical reduction, the NAC is translocated superiorly, and breast skin is removed only in the vertical dimension, resulting in vertical scar inferior to the NAC.[10] The use of an inferiorly based deepithelialized dermal flap has been described as a means of circumventing the poorly perfused T-point and improving outcomes following Wise pattern mastectomy with immediate autologous reconstruction.

Intraoperative assessment of mastectomy skin flap perfusion is essential and may be augmented with the use of indocyanine green angiography. When faced with a significant area of poorly perfused mastectomy skin, it may be necessary to abort the reconstruction entirely. Alternatively, some authors argue for banking of the free flap underneath the mastectomy skin, without de-epithelializing the flap. Notwithstanding the risks of additional surgeries, this approach allows the mastectomy skin to demarcate and may improve overall flap survival.[11] Also, noninflated tissue expanders can be placed at the time of mastectomy, and inflated postoperatively. This practice allows mastectomy skin to heal without underlying pressure. After the incisions have healed, tissue expander volumes can be gradually increased to create adequate volume for an autologous flap, at which point the expanders can be removed, and an microsurgical autologous flap reconstruction can be performed.[12]

Patients deemed to be at high risk for postoperative complications, particularly donor-site wound complications, may benefit from the application of closed incision negative pressure wound therapy (NPWT) following wound closure. Closed incision NPWT is believed to accelerate the wound healing process by means of augmenting blood flow to the incision site, improving wound perfusion, and minimizing edema. Retrospective studies suggest that its use may significantly reduce the risk of abdominal donor site complications following autologous breast reconstruction.[13]

As previously mentioned, close communication among members of the patient's multidisciplinary team is particularly important: Coordinated efforts may improve patient outcomes without compromising oncologic disease control. A patient-centered preoperative consultation will help manage expectations, optimize flap outcomes, and reduce donor-site morbidity. Management options for potential complications should also be outlined preoperatively. Finally, careful decision-making and meticulous surgical technique to prevent wound complications are particularly important in oncologic cases, given the time-sensitive nature of adjuvant therapy.

Management

Microsurgical autologous breast reconstruction has a well-tolerated safety profile, with major flap complication rates as low as 2% and minor wound-related complication rates around 10%.[14] Delayed wound healing is often the most frequent complication encountered. Initial management involves medical optimization, including glycemic control and nutrition support, in addition to local wound care. A moist environment, ideal for wound healing, is easily achieved with the use of simple wet-to-dry dressings. Alginate and silver-based dressings also may play a role in expediting wound healing. More aggressive debridement of devitalized or fibrinous tissue can often be accomplished in the office at subsequent follow-up visits and as tissue begins to demarcate. Local infection may contribute to prolonged wound healing, and thus antibiotic therapy with good coverage of skin flora should be initiated at the first sign of infection.

Mastectomy skin flap necrosis

Mastectomy skin flap necrosis (MSFN) is a potentially more significant wound complication that may threaten the reconstruction. Although definitions vary, the incidence of MSFN may be as high as 45%.[15] Management can be both costly and time intensive; studies have demonstrated that local wound care and office

debridement alone can result in wound healing times upward of 120 days.[16] The development of MSFN is multifactorial, and, as previously mentioned, strategies to identify and address skin flap ischemia intraoperatively are critical to the longevity of the reconstruction. Early recognition and management are equally important postoperatively.

Ultimately, approaches to management of MSFN depend on the extent of the wound and the patient's tolerance for delayed adjuvant care, need for reoperation, and transient aesthetic deformity. Early skin grafting of clean, healthy wound beds reduces metabolic demand and obviates the need for prolonged daily dressing changes. However, this comes at the expense of an additional donor site and often results in a suboptimal aesthetic outcome. Alternatively, with gradual wound contraction over time, delayed primary closure may offer the best aesthetic result if the patient can tolerate prolonged local wound care. Nykiel et al[16] proposed an algorithm for the management of MSFN. Their results support that patients with a high body-mass index and those with full-thickness wounds greater than 6 cm^2 would benefit from operative debridement and skin grafting, ideally with a full thickness skin graft. Partial-thickness wounds smaller than 5 cm^2 would be amenable to local wound care. Office-based debridement would be appropriate for partial- and full-thickness wounds greater than 5 or 6 cm^2, respectively.[16] Regardless of the initial approach to MSFN management, delayed revision is often necessary to improve scar appearance and overall breast aesthetics.

Hyperbaric oxygen therapy

Hyperbaric oxygen therapy (HBOT) has recently gained popularity as a valuable adjunct to traditional wound care. Briefly, HBOT involves the delivery of high levels of oxygen at elevated atmospheric pressures to boost the oxygen-dependent wound-healing pathways. Specific regimens vary based on patient and wound-related factors, but generally involve daily treatments in a hyperbaric chamber for 60 to 90 minutes. Importantly, the role of HBOT exists in concert with local wound care, manual debridement, delayed primary closure, or coverage with a skin graft. The efficacy of HBOT in the treatment of chronic wounds is well-documented, and recent studies have demonstrated its efficacy in the setting of acute and progressive wounds as well.[17] In this evolving body of literature, single-institution experiences highlight the utility of HBOT in the early treatment of MSFN, particularly in terms of reconstructive salvage and aesthetic outcomes. A 2021 study from Meier and colleagues[18] analyzed the perioperative application of HBOT in irradiated patients undergoing secondary breast reconstruction. Despite a small sample size, logistic regression analysis identified perioperative HBOT as a protective factor against postoperative complications compared with lifestyle- and disease-matched control groups. Multi-institutional studies and RCTs are needed to better define the magnitude of potential benefits that can be expected with HBOT, adverse effects, cost analysis, and treatment timeline specifically as it pertains to oncologic and reconstructive care.

Unique Considerations

Pyoderma gangrenosum

Pyoderma gangrenosum (PG) is a rare but potentially devastating ulcerative skin pathology that has been reported in patients undergoing autologous breast reconstruction. Distinguishing PG from the frequently encountered minor wound complications can be challenging and requires a high index of suspicion because management strategies are fundamentally different. Pyoderma gangrenosum is presumed to be a disorder of neutrophilic dysfunction, with an estimated annual incidence of 3 to 10 cases per million population.[19] Clinically, PG can present after even minor skin trauma, and it manifests with ulcerative, bullous, pustular, or vegetative skin lesions that can progress to a painful, necrotic, and potentially purulent wound base. Fever and other systemic symptoms may also be present, which, together with the wound appearance, can make PG difficult to distinguish from an infectious process. Although PG is thought to be idiopathic in 25% to 50% of cases, it is frequently associated with underlying systemic diseases, most commonly autoimmune diseases (eg, inflammatory bowel disease, rheumatoid arthritis), but also breast cancer, endocrine diseases (eg, diabetes, thyroid disease), hematologic disorders, and collagen vascular disorders. Most importantly, these lesions are unresponsive to antibiotics and often demonstrate the phenomenon of pathergy—the aggravation of existing lesions or development of new lesions in response to trivial trauma. Thus, surgical debridement should be avoided if possible. Although diagnosis relies on histopathologic assessment, treatment should not be delayed if there is a high index of suspicion. Topical corticosteroids or cyclosporine in conjunction with wet-to-dry dressings may be sufficient for mild cases. Patients with more significant disease generally require systemic therapy with corticosteroids.[19]

SCARRING

Prevention and management of postoperative scarring are pillars of plastic surgery. Decades of innovation and technical refinements have enabled safe and reliable microsurgical autologous breast reconstruction, and most surgeons now also view aesthetic outcome as a critical metric of success. Numerous strategies and biotechnical products have been designed to assist in achieving this goal, and the accompanying literature is expansive. Evidence-based approaches to scar prevention and management are particularly valuable in this patient population, given the morbidity of two (or more) surgical sites and the propensity for poor healing from chemoradiation. A thorough review of the literature is necessary to distill data relevant to breast and abdominal scars from the large body of research on facial scar therapy. Validated instruments for scar

TABLE 1. VANCOUVER SCAR SCALE

Scar Characteristics	Score
Vascularity	
Normal	0
Pink	1
Red	2
Purple	3
Pigmentation	
Normal	0
Hypopigmentation	1
Hyperpigmentation	2
Pliability	
Normal	0
Supple	1
Yielding	2
Firm	3
Ropes	4
Contracture	5
Height, mm	
Flat	0
<2	1
2-5	2
>5	3
Total	13

assessment, such as the Vancouver Scar Scale (Table 1) and Patient and Observer Scar Assessment Scale are essential for standardizing comparisons and interpreting the available evidence. Although clinically relevant, the pathophysiology and approaches to treatment of keloid scars remains outside of the scope of this review.

Scar Prevention

Surgical technique

Tension is one of the primary drivers of increased scar formation, likely through a combination of fibroblast proliferation and a compensatory overproduction of collagen. A 1983 study by Wray demonstrated this relationship between tension and resulting scar width among women undergoing reduction mammaplasty.[20] Standard closure of most breast and abdominal incisions involves a robust deep dermal layer, often followed by an intradermal or subcuticular layer. However, there is data to suggest that tissue adhesives and self-adhering mesh products may be used in lieu of subcuticular closure with equivalent scar-related outcomes.[21] Although barbed sutures have become quite popular, multiple studies evaluating their impact on aesthetic outcomes have failed to demonstrate an improvement in scar appearance.[22] A final technical point, specifically regarding abdominally based autologous breast reconstruction, is the influence of closing the superficial fascial system. A retrospective review from Mathes et al[23] demonstrated no difference in abdominal donor site scar appearance whether the Scarpa fascia was closed.

Considering that maximum scar strength is not reached until roughly 12 weeks, many popular postoperative dressings are designed to offer continued tensile support. A 2005 RCT found that application of paper tape over 12 weeks resulted in a significant reduction in cesarean section scar volume and rate of hypertrophic scarring.[24] The Embrace device (Neodyne Biosciences Inc) employs a tension-offloading silicone elastomer that can be applied following wound closure and reapplied weekly for up to 13 weeks. In a split-scar RCT, the Embrace device demonstrated improved scar pliability, texture, pigmentation, and vascularity at 12 months following abdominoplasty.[25]

Force modulating tissue bridges, such as the Brijjit device (Brijjit Co LLC), are a new class of wound closure adjuncts that have been shown to significantly reduce tension in animal models, although rigorous clinical data have not yet been published.[26] Similarly, preclinical studies on incisional NPWT suggest a potential role in scar reduction; however, clinical results are mixed and of lower quality.

Scar Management

Topical products

Maintaining a moist environment has been shown to accelerate wound epithelialization, and thus is an essential component of early postoperative wound care.[27] Antibiotic and petroleum jelly ointments are commonly used, low-cost products that can be applied immediately following wound closure and serially reapplied in the first few weeks after surgery. Sunscreen is another important component of scar prophylaxis. Wounds less than 12 to 18 months old are particularly susceptible to ultraviolet radiation damage, leading to hyperpigmentation and structural changes to the collagen matrix.[28]

There are numerous over-the-counter topical scar therapies, which may be applied as early as 1 to 2 weeks postoperatively. The most common ingredients in these products are vitamin E, onion extract, or silicone. Vitamin E functions in wound healing by inhibiting collagen synthesis. Level I studies have repeatedly found no benefit from vitamin E compared with plain moisturizer, but rather a higher incidence of contact dermatitis.[27]

Onion extract, the active component in Mederma Scar Gel (Merz Pharmaceuticals), has been reported to improve scar size (height and width), erythema, and pruritis through inhibition of fibroblast proliferation and upregulation of matrix metalloproteinase-1. However, level I and II studies have largely failed to demonstrate clinical efficacy of onion extract in the prevention or treatment of surgical scars.[27]

Treatment with silicone-based products may begin as early as 2 weeks postoperatively and often continues for up to 3 to 6 months. Numerous mechanisms have been proposed, from simply providing hydration/occlusion to polarizing the scar's electronegative charge. Silicone products have a demonstrable role in preventing and treating hypertrophic scars as well as in improving scar pliability, pigmentation, and vascularity (level I and II studies).[29] Although there does not appear to be a clinical difference between sheet versus gel formulation, the latter offers greater ease of use.

Lasers

The use of laser therapy for scar prevention and management has expanded significantly in recent years, as new devices, strategies, and data are published. Early use of laser therapy at surgical sites in the early postoperative period can provide a prophylactic benefit of reducing long-term scar appearance.[2] Although precise mechanisms may vary, all lasers induce some degree of tissue damage and exploit the regenerative process to improve scar appearance. Split-scar studies on both breast and abdominal incisions have shown the potential prophylactic benefit of early treatment with combined pulse-dyed laser (PDL) with neodymium-doped yttrium aluminum garnet (Nd:YAG),[30] 1210-nm diode laser,[31] and ablative CO_2 fractional laser.[32] In the setting of autologous breast reconstruction, however, the additional insult and subsequent wound healing demands from laser therapy might impart an increased risk of complications.

Potentially, a more widespread use for laser therapy may be the treatment of established scars. A 2013 systematic review and meta-analysis found the PDL and CO_2 fractional laser to have the highest efficacies in scar treatment.[33] The PDL tends to have greater effects on scar vascularity and pigmentation,[34] whereas the CO_2 fractional laser can improve scar texture, pliability, and height.[35]

Injections

Direct injection of therapeutic agents, including corticosteroids, 5-fluorouracil (5-Fu), and bleomycin, is a well-established treatment option for unsatisfactory scars. Corticosteroids, such as triamcinolone acetonide, suppress TGF-β_1 activity thereby stimulating collagenase-mediated degradation of collagen.[27] Triamcinolone acetonide 10 mg/mL, often mixed with equal parts 1% lidocaine with epinephrine 1:100,000 is typically administered at a dose of 0.5 to 1.0 cc/cm^3, and can be given every 4 to 6 weeks.[2] A 2006 RCT by Asilian et al[36] found that weekly injections of triamcinolone acetonide resulted in significant improvements in scar pliability and thickness. The addition of 5-Fu, an antimetabolite agent, provided further reduction in scar height and improvement in pliability.[36] The risk of scar atrophy and emergence of telangiectasias does increase with repeated corticosteroid injections, although a true scientific threshold has not been established. Further, both corticosteroids and 5-Fu are associated with pigment changes, particularly in individuals with darkly pigmented skin.

Recently, the role of Botulinum neurotoxin type A (BoNT-A) has been investigated for its potential to treat the appearance of scars. Several theoretical mechanisms have been described, including immobilization of healing wounds and modulation of fibroblast activity.[37] Indeed, two double-blinded split-scar RCTs found that BoNT-A injections lead to significant improvements in the width, height,

color, and visibility of sternotomy,[38] reduction mammoplasty, and abdominoplasty[37] scars.

Fat grafting has gained popularity in plastic surgery because of its numerous applications, one of which is being yet another potential option for scar treatment. In addition to the direct effect of volumetric filling, scars may benefit from neoangiogenesis induced by adipose-derived stem cells. Although rigorous level I evidence is lacking, several small studies have shown improvements in scar appearance and characteristics following autologous fat grafting.[39] The impact of fat injections may be bolstered with percutaneous aponeurotomy, or 'Rigottomy.'[40]

Mechanomodulation

Mechanical modulation of the local wound environment may also have a role in scar management. Scar massage is often advised beginning roughly 2 to 3 weeks postoperatively, once the incision has regained enough tensile strength to support additional gentle pressure. Level I and II studies support the role of scar massage in improving pain, pruritus, pliability, and thickness.[41]

Microneedling and dermabrasion are popular techniques for treating facial scarring, rhytids, and dyschromia that have recently been studied in nonfacial postsurgical scar treatment. Both techniques leverage the skin's regenerative properties following controlled microinjuries to improve scar appearance. Small studies involving microneedling suggest that improvements in scarring might be greater during the early maturation phase (postoperative weeks 6 to 7 vs weeks 13 to 16).[42]

Camouflage

Medical tattooing is a more recently described option for camouflaging postsurgical scars, particularly those that may have failed conventional treatment or have contraindications. The ability to obtain an excellent color match to the surrounding skin is one of the principal advantages of this technique. Several single cohort studies on medical grade tattooing for the concealment of scars have demonstrated favorable results.[43]

Operative revision

For postsurgical scars that remain unsightly despite intervention, scar revision may be indicated. According to data from the Mastectomy Reconstruction Outcomes Consortium published in 2019, the rate of elective revisions following abdominally based autologous breast reconstruction was nearly 60%.[1] Thus, scar management in this setting may be delayed until final revisions are complete.

CONCLUSIONS

The ultimate goals of microsurgical autologous breast reconstruction appeal to both aesthetic and general reconstructive principles. Careful preoperative planning and shared decision-making should be used to address unique patient factors and minimize the risk of developing wound complications. Subsequent timely recognition and prompt treatment of wound complications will avoid delays to oncologic care and may improve patient satisfaction with their reconstruction. Local wound care, mechanical or enzymatic debridement, hyperbaric oxygen therapy, and surgical revision are all important techniques in the armamentarium of the microvascular surgeon.

Ultimately, the strategies and products outlined in this review are likely to have the greatest impact when used in conjunction and according to the scar characteristics that are most bothersome to the patient. A tension-free closure and moist postoperative wound environment with the addition of silicone are likely to reduce the risk of hypertrophic scarring. As the scar matures, PDL treatments may help address areas of erythema and vascularity while injections with triamcinolone or 5-Fu tend to reduce scar height and improve pliability. The addition of CO_2 laser treatments, microneedling, or dermabrasion may offer a refined scar texture. However, many patients will see elective revision, and thus careful consideration should be given to the potential risks associated with various scar interventions.

PRACTICE PEARLS

- Postoperative wound complications and unsightly scars can profoundly affect outcomes following breast reconstruction.
- Careful preoperative planning, patient optimization, and shared decision-making are critical for risk reduction.
- Surgeons should be comfortable with traditional and novel approaches to wound management.
- Meticulous surgical technique, thoughtful postoperative dressings, and prompt introduction of therapeutics are necessary components of minimizing scar burden.

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