Current Techniques for Burn Reconstruction

Using Dehydrated Human Amnion/Chorion Membrane Allografts as an Adjunctive Treatment Along the Reconstructive Ladder

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Abstract: The reconstructive ladder is a term coined by reconstructive plastic surgeons to describe levels of increasingly complex management of wounds. The first rungs of the ladder is allowing the wound to heal by secondary intention, advancing up the ladder to direct tissue closure, with skin grafting and tissue transfer (flaps) comprising the higher rungs. Skin grafting and tissue transfer (flaps) at the middle and higher rungs of the ladder are often necessary for the treatment of complex burn injuries. Our purpose is to describe how dehydrated human amnion/chorion membrane allografts may be used as an adjunctive treatment.

Key Words: burns, dehydrated human amniotic membrane, grafts, tissue transfer, reconstructive ladder

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One of the main tenets of reconstructive plastic surgery is that of the reconstructive ladder which is characterized by using the simplest option available with the least potential for morbidity.[1] The first rung of the ladder represents allowing the wound to heal by secondary intention, advancing up the ladder to direct tissue closure, with skin grafting and tissue transfer (flaps) comprising the higher rungs (Fig. 1). The reconstructive surgeon considers a variety of clinical factors and quality of life issues when determining which techniques to use, and the timing of the intervention to best meet the goal of wound healing and reconstruction.

In patients with severe burns, modulation of inflammation, avoidance of infection, fluid resuscitation, and nutrition are the basic tenets of treatment.[2] Inflammation is essential for wound healing, yet aberrant inflammatory pathways have also been linked to hypertrophic scarring. Functioning as a barrier to the external environment, the skin maintains fluid homeostasis and body temperature and provides sensory information as well as metabolic and immunological support. Damage after a burn disrupts the intrinsic immune system and increases susceptibility to bacterial infection.[3]

For decades, early excision and grafting have been the standard of care for burn injuries. Patients with more extensive burns often require temporary coverage with an allograft, xenograft, skin substitute, or dermal analog due to insufficient or unavailable donor sites, whereas autografts remain the criterion standard burn covering. Flaps may be necessary in cases where a wound cannot sustain a graft or in later stages where further reconstruction is necessary for range of motion, function, or cosmetic reasons. Flap surgery is a technique where any type of tissue with an intact blood supply is lifted from a donor site and moved to a recipient site. This is similar to but different from a graft, which does not have an intact blood supply and therefore relies on growth of new blood vessels (angiogenesis). In patients with more extensive burns, or in cases with insufficient or unavailable donor sites, temporary or permanent burn coverage with an allograft, xenograft, skin substitute, or dermal analog may be necessary.[2]

Human amniotic membrane allografts have been shown to have numerous beneficial properties which suggest its use as an effective treatment for burn injury, including creation of a natural biological barrier and reduction of pain, promotion of increased healing, modulation of inflammation, and reduction of scar tissue formation.[4] Amniotic membrane contains collagen and growth factors, is self-signaling, and has antibacterial and pain reduction properties.[4] Our purpose is to review how a commercially available dehydrated human amnion/chorion membrane (dHACM) allograft (EpiFix, EpiBurn; MiMedx Group Inc., Marietta, Ga) can be used at various rungs on the reconstructive ladder in patients with burns.

REVIEW OF RECONSTRUCTIVE LADDER TECHNIQUES

Secondary Intention

Second-degree burns are often allowed to heal with local wound care alone. Secondary intention is when skin edges of the wound are not sutured together. The wound is left "open" with regularly applied dressings to control exudate and keep the wound clean. The wound gradually closes and heals on its own.[1] Secondary wound closure is the simplest and, therefore, lowest rung on the "reconstructive ladder." Negative aspects of allowing a wound to heal by secondary intention are related to the extended healing period and possibly burdensome dressing changes, as well as the pain associated with dressing changes and an open wound. Wounds allowed to heal by secondary intention may have larger and more noticeable scars and have a greater tendency for keloid formation than scars resulting from primary closure. Scars resulting from wounds healed by secondary intention are also less stable and are prone to reopen.[5]

Primary Closure

Primary wound closure facilitates the biological event of healing by joining the wound edges using sutures, staples, Steri-Strips or adhesives. Surgical incisions, cuts, and small cutaneous wounds usually heal by primary closure.[1] Primary closure reduces the risk of infection and requires new blood vessels and keratinocytes to migrate only a small distance. In burn wounds, primary closure may be used to close areas where autografts were harvested or after burn excision if the surrounding skin is able to stretch and be joined, or small burn defects which can be primarily excised. Primary closure may also be used for burn scar revision. Delayed primary closure of burn wounds may be necessary when a patient is initially unstable or transfer to a facility able to treat their burn injury has been delayed.[6]

Skin Grafts

The physiological basis for skin autografting relies on the skin's ability to incorporate live cells back into the dermal structure.[7] It does

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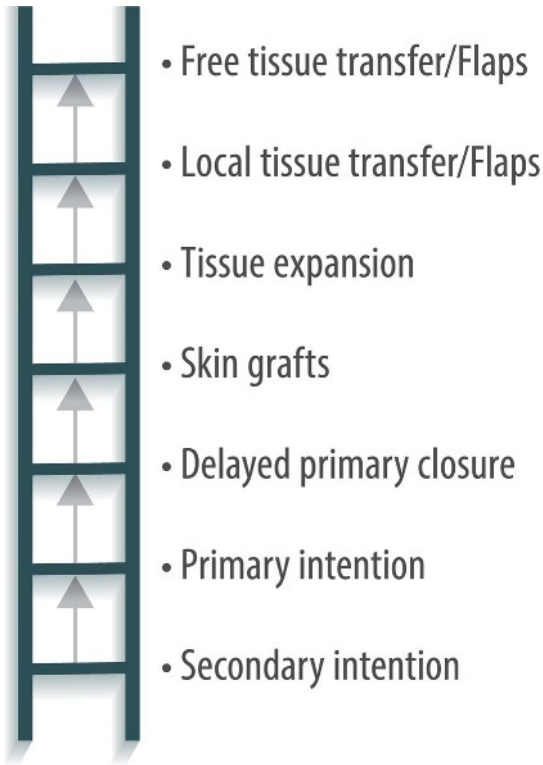

FIGURE 1. The reconstructive ladder.

this by first sustaining the cells through a process call imbibition (Latin "to drink"). Usually, the first 48 through 72 hours after the skin graft is placed, the skin cells survive on the diffusion of oxygen and nutrients through the extracellular matrix. During this time, angiogenic growth factors are released, and vessels grow into the graft to reestablish a regular blood supply. After the reestablishment of vessels, the graft matures and becomes more durable through the regular healing process.

Skin grafting relies on multiple factors for success.[6] Primary among these factors is that the graft bed has the right conditions to sustain the graft during the imbibition phase and also has the ability to incorporate the graft into the bed. Graft beds that do not have a sufficient perfusion, or are unable to supply the growth factors necessary for incorporation, will result in graft failure. In addition, bacterial overgrowth during the early phases of graft incorporation will also result in the loss of the graft.

Presently, there are few modalities that will aid in the improvement of a wound bed before grafting. Improving perfusion through vascular surgery, hyperbaric oxygen therapy, and the control of biofilm and bacterial colonization will aid in the preparation of the bed and improve the wound as a whole. However, once the wound has been optimized and the wound bed still cannot sustain a graft, flap surgery has been the next step in treatment.

Tissue Expansion

Skin responds to mechanical stress. By expanding local skin surrounding the injured area, wound coverage is provided with tissue that carries similar color and texture without compromising the donor area. Tissue expansion is a specialized use of local flaps along a higher rung of the reconstructive ladder. An expander is placed in nonburned adjacent tissue and slowly inflated to create new tissue. Once the expander is removed, the extra skin can be used to replace lost tissue.

Local and Regional Skin Flaps

Patients with severe burns complicated by severe tissue loss with exposed, critical deeper structures are often not able to be adequately reconstructed with the simplest reconstructive options, including the gold standard of burn reconstruction, the split-thickness autograft.[8–10] In addition, due to the improvements in burn management and resuscitation, many patients having severe burns with large total body surface area involvement are now surviving their burns and are often left with significant scarring requiring complex reconstruction. Quality of life of these patients can be greatly enhanced by providing good quality tissue flaps to these scarred areas to increase range of motion and function.

Flaps are not generally used as a primary reconstructive option. They are typically done as a later stage of treatment after the initial resuscitation or after scarring has occurred.[8] High-voltage electrical injuries may be the exception, often requiring multiple composite layers of tissue to reconstruct the significantly damaged hand, arm, or lower extremity or to cover exposed joints. In addition, bringing in vascularized and tissue with nerve supply can create a functional extremity.

Flaps can be divided into various types based on a variety of classification systems which are defined by the location of the donor area, type of tissue utilized and if it maintains its blood supply via random or axial vessels.[10] The typical flap used in burn reconstruction is a fasciocutaneous flap, bringing full-thickness skin and fascia to the area which is often the tissue that is lacking in burn patients. Muscle or myocutaneous flaps may also be used to cover large areas of muscle and tissue loss and to cover exposed bone. Additionally, functional muscle flaps, such as a latissimus dorsi flap, can be used to restore function to the upper extremity.

The simplest flap available is the local flap.[9,10] These flaps have a random blood supply and provide adjacent tissue that is cut and moved into the burned or scarred area. The most common flap used in burn reconstruction is the Z-plasty. This method consists of 2 triangular flaps transposed to increase the length of the contracted scarred area and are frequently used in the extremities, axilla or neck where a clear scar band is restricting growth or movement. Other flaps in this category include the rotation flap and advancement flap.

Regional flaps, such as a latissimus dorsi myocutaneous flap, take a large volume of tissue attached to its blood supply and move it into an area where large tissue loss has occurred or where functional muscle is needed. These types of flaps can be versatile but are limited by the length of their blood supply.

Lastly, at the highest rung of the reconstruction ladder, the microvascular free flap has become more available in recent years due to the versatility and variability which have expanded their indications in burns. These flaps are rarely needed but can provide vital coverage to exposed bone, nerves, and blood vessels. These require specialized teams of microsurgeons and often very long surgical times. The type of flap can be tailored to the anatomic area involved.

USING DEHYDRATED HUMAN AMNION/CHORION MEMBRANE ALLOGRAFTS ALONG THE RECONSTRUCTIVE LADDER

Dehydrated human amnion/chorion membrane (EpiFix or EpiBurn; MiMedx Group Inc.) is a human derived placental tissue that has been shown effective for the treatment of difficult to heal wounds.[11,12] The allografts have been shown to contain growth factors and cytokines, including immunomodulatory chemokines, immunomodulatory cytokines, and tissue growth promoting factors.[13–15] Angiogenic growth factors retaining biologic activity are present in dHACM, and in an in vivo model a steady increase in microvessels was observed in dHACM implants over a 4-week period.[15,16] In vitro studies have shown the tissue product to also have the ability to attract stem cells to the area of the wound.[16,17]

The characteristics of dHACM are desirable for the treatment of a variety of wound types including burns. In our practice, we have found that dHACM can be a beneficial adjunctive treatment along the reconstructive ladder.

Secondary Intention

Providing wound coverage with a dHACM allograft when allowing a burn to heal by secondary intention may reduce pain and reduce time to closure and reduce or eliminate the need for skin grafting.

Primary Closure

Although with this procedure the wound is closed, in some cases, it may be appropriate to place dHACM into the wound before closure to modulate inflammation and assist in regulating the healing process, which may result in a greater durability of the healed area and less scarring.

Skin Grafts and Flaps

Application of dHACM over donor sites where skin grafts or flaps were harvested may provide a bioactive wound covering resulting in reduced pain and more rapid healing. The dHACM allograft may also be helpful in preparing a site for autografting or in areas where grafting attempts have failed.

OUR EXPERIENCE

We use a combined use protocol with dHACM in the setting of previous failed skin grafting or poor skin graft wound beds where grafting was deemed not likely to be successful. Combined therapy has been used before grafting to prepare the wound bed. Anecdotal reports of dHACM used in lieu of skin grafting suggest a more durable and vascular graft than where dHACM was not used. The following cases are representative of our experience using EpiBurn.

Case 1

A 2-year 6-month-old male infant burned after placing his hand in a cup of hot water. He was treated with 1 application of EpiBurn (dHACM) and was able to be sent home from the hospital on the same day. He returned to the office for follow-up 7 days later, where the dressing was taken down; the hand and fingers had good range of motion, and he could open and close his fingers. The hand was then noted to heal over the next 5 days without sequelae (Fig. 2).

Case 2

A 16-month-old child pulled hot tea onto the right shoulder and chest. The child suffered a mixed pattern of deep and superficial burn to chest and left shoulder. In the operating room on day 2, a debridement was performed, and EpiBurn (dHACM) was applied. The cover

FIGURE 2. Toddler with scald burn of hand. A, Initial presentation and application of EpiBurn. Front and back of hand. B, One week later. C, Healed, 12 days postburn.

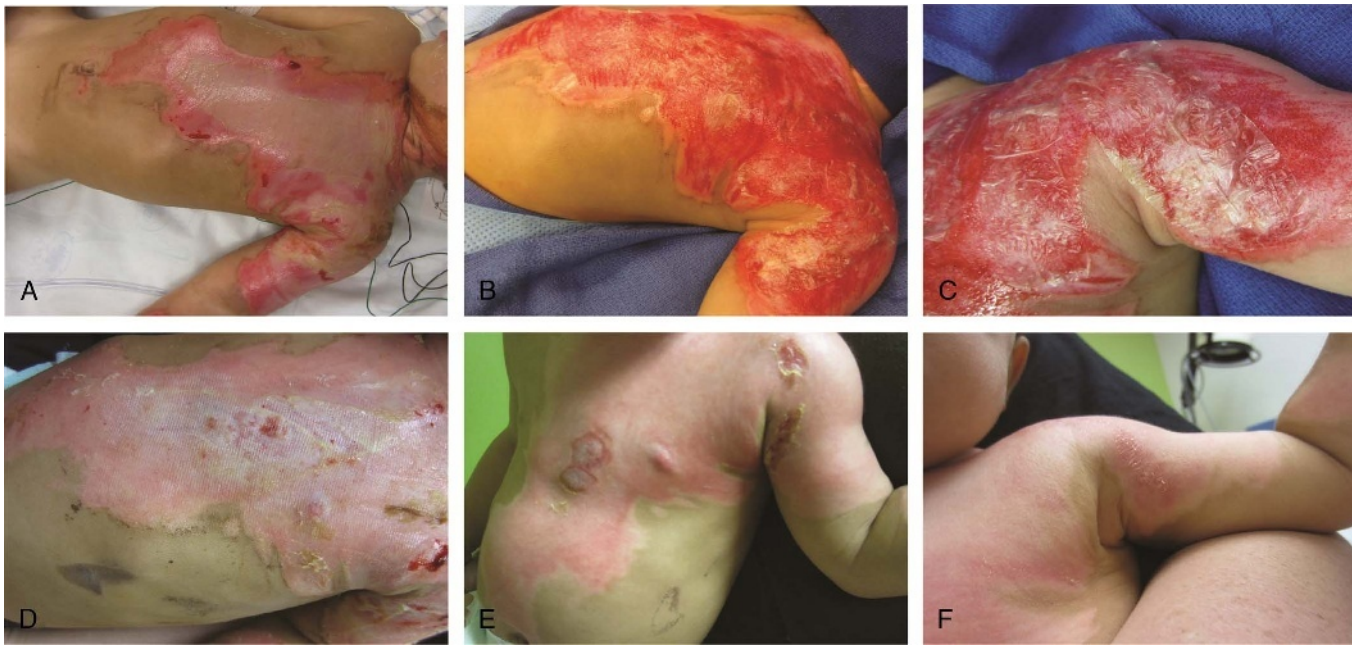

FIGURE 3. A 16-month-old child with scald burn to chest and shoulder. A, At initial presentation. B, Two days later. C, Debrided in OR with EpiBurn application. D, One week later. E, Two weeks later. F, Healed 4 weeks after EpiBurn application.

FIGURE 4. A 4-year-old child with deep partial-thickness burn to palm. A, Initial presentation. B, Application of EpiBurn. C, Fully healed after 14 days.

dressing was Mepilex Ag antimicrobial foam dressing. The dressing was changed at 1 week, and the injured area was found to be mostly healed but there were some open areas in central chest and shoulder (deepest areas). Mepilex Ag was reapplied. At 2 weeks, all healed except the central chest. This area was treated with 1 more week of Mepilex Ag. All burns were healed by 4 weeks. There was minimal scarring in the central chest but no skin graft used and no donor site morbidity. This represents a successful use of a dHACM allograft in lieu of a skin graft (Fig. 3).

Case 3

A 4-year-old boy touched a hot fire pit. He sustained deep partial-thickness burn to his palm with minimal bleeding and whitish appearance. He was debrided in OR postburn day 3. EpiBurn (dHACM) was applied. It was covered with Mepilex Ag. The hand was fully healed by day 14 with a single application. There was no scarring. This represents a successful use of a dHACM allograft in lieu of a skin graft (Fig. 4).

CONCLUSIONS

A reconstructive surgeon has several options when establishing a treatment plan for a patient presenting with severe burns. Autografts are the criterion standard, but flaps are often needed to provide better quality and thickness of tissue to the affected areas. Allografts with bioactive properties, such as dHACM, may play an important role on many rungs of the reconstructive ladder and can be used in addition to, and in some cases in lieu of, grafts and flaps.

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