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Basic techniques for optimizing burn wound healing: insights from clinical practice

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Abstract

The purpose of this paper is to provide the author's view on basic techniques to optimize burn wound healing. For burns that are partial thickness, the goal is to optimize re-epithelialization to reduce the chance of hypertrophic scarring. For deeper burns, there are principles that lead to better outcomes. For very small burns, such as on the hand, full-thickness skin grafts can be performed in the outpatient setting. For burns requiring split-thickness skin grafts, thicker grafts tend to contract less than thinner ones. Using wider skin grafts or breaking up straight seams with darts also leads to improved results. Choosing donor sites that either minimize scarring or can be hidden should also be considered. For the massive burn, one must still prioritize better grafts for more functional or cosmetic areas (face, hands). Early excision and coverage should reduce scarring. Despite the availability of newer technologies, simple strategies to treat the burn wound still lead to excellent results.

Keywords: Burns, skin grafts, scarring, epithelialization, wound healing

INTRODUCTION

The primary task for treating burn patients is to heal their wounds with minimal scarring. Often, complete regeneration of the original tissue is not feasible, so the focus should be on optimizing both functional and cosmetic outcomes. While many new products and techniques exist, optimal outcomes can often be

achieved through straightforward strategies utilizing resources available to surgeons in any environment. The aim of this paper is to outline simple strategies, especially surgical techniques, that any surgeon worldwide can implement. While other papers in this Special Issue will cover additional options, this document focuses on techniques that necessitate only very basic instruments, drawing from the author's own experience. Effective burn wound treatment varies depending on the extent and depth of the injury. This article first addresses superficial wounds, which may heal naturally. It then discusses deeper wounds that are more prone to hypertrophic scarring, emphasizing that smaller burns are easier to treat than extensive ones. Surgical strategies are presented for very small burns, larger wounds treatable in a single procedure, and finally, optimal wound closure for massive burns. These strategies aim to help patients regain normalcy in their lives, underscoring their significant impact on burn survivors' quality of life.

OPTIMIZING WOUND CLOSURE IN SUPERFICIAL BURNS

Many superficial burns heal without any scarring, but deeper burns may scar. The goal for partial-thickness burns is to reduce the chance of developing a hypertrophic scar. Unfortunately, the chance of developing a hypertrophic scar increases dramatically in an open wound after 2-3 weeks[1,2]. Since partial-thickness burns heal by re-epithelialization, the goal should be to optimize epithelial migration to close the wound within that 2-3-week period. Since the epithelial cells migrate across the viable wound bed, any factor that impairs this progress will increase the chances of the wound developing a hypertrophic scar. Migration occurs most easily if the wound remains moist and free of debris. Since partial thickness burns weep serum and interstitial fluid, maintaining that moist environment provides optimal conditions for migration. If the wound dries, however, the protein in the fluid dries to form a "scab" that impairs migration. Since they must maintain contact with the viable wound bed, the migrating epithelial cells must use proteases to digest away the scab. Therefore, wounds that are allowed to desiccate always take longer to heal than those that maintain a moist surface. Wounds will heal faster if they are covered with an ointment, or if they are covered with a dressing that adheres to the wound but maintains a moist environment. There are many products that are designed to adhere to the wound and can be left in place for up to 7-10 days. These dressings also reduce pain by covering the wound and reducing the need for painful changes. Investigators have also found that cellular products and recombinant growth factors accelerate wound re-epithelialization, but from the beginning, it was found that the acceleration was not greater than a day[3,4]. The use of products containing allogeneic cells is now being tested to improve burn wounds that are of indeterminate depth[5]. It is still not clear if cell-based products will replace acellular dressings due to their increased cost. Once the wound is open for 2-3 weeks, a different strategy is needed to optimize functional and cosmetic outcomes.

OPTIMIZING OUTCOMES FOR DEEP SECOND AND THIRD-DEGREE BURNS

The management of burns becomes more complicated when a wound remains open for longer than 2-3 weeks. As always, the goal is to keep scarring to a minimum and, if possible, return the wound to as close to normal skin as possible. The decision to graft or wait for spontaneous healing is not always easy. One of the problems is that burns frequently have mixed depths, so healing in one area may be delayed, while the rest of the injury heals quickly. Differences in depth are common since many factors influence burn depth - temperature of the burning agent, how the heat is transferred, duration of contact, thickness of skin, and local blood supply. While hotter agents typically cause deeper burns, different body areas may experience varying degrees of impact from the agent. Heat transfer to tissues is more efficient through direct contact with metal or liquid compared to heat carried through the air (such as in a flash or explosion). Duration of contact is one of the most influential factors affecting burn depth. For instance, if hot liquid spills onto a child wearing only a diaper, the water slides off the chest quickly and the short duration of contact leads to a more superficial burn. However, the hot water that soaks into the diaper will have

prolonged contact and thus will be deeper. The thickness of the skin also matters. For instance, a flash burn to the hand and forearm will have varying depths. The palm, with its thicker skin, often heals without scarring. In contrast, the skin on the dorsal hand and especially the volar forearm is thinner, making these areas more susceptible to deeper burns. Additionally, the face, being highly vascularized, dissipates heat quickly due to its dense blood flow, thereby reducing burn depth.

Managing burns of varying depths can be difficult. For instance, if 90% of a chest burn heals within 2 weeks, but there are persistent open spots after 3 weeks, should these areas be grafted? Small grafts within an otherwise unscarred wound are quite unsightly. However, removing a larger area that includes healed burns is also not ideal. Sometimes, leaving small areas to scar naturally is a better option, as small scars may be less noticeable compared to small grafts, which often differ noticeably in color and can be surrounded by hypertrophic scars. Moreover, hypertrophic scars may be managed more effectively than attempting to remove an ugly graft. Additionally, there are certain body areas that do well with contraction. Areas with lax skin, such as the abdomen or buttocks, often contract with little hypertrophic scarring. Therefore, considering the laxity of the skin surrounding the burn is crucial. All grafts tend to contract to some extent, but the tautness of the surrounding skin counteracts wound contraction. For instance, an isolated skin graft on the inner aspect of the upper arm tends to contract because this skin is quite loose and does not resist contraction [Figure 1]. The outer arm, however, has less mobile skin and thus resists shrinkage. The same can be said for the face. A graft on the taut forehead performs much better than a small graft on the mobile cheek. When large areas of the body, such as the entire arm, are covered with a sheet autograft, deformities are minimized because all the forces tend to cancel each other out.

Once the decision to graft is made, there are several treatments and techniques available to optimize the cosmetic and functional outcomes of the graft. First, it is much easier to treat small burns with optimal outcomes since there is plenty of donor skin. For larger burns, there is a concern about donor skin availability, so one must consider meshing the skin to cover greater surface area. The depth of injury also influences the choice of treatment. A small, uncomplicated third-degree burn can be treated with a more cosmetic graft. When a wound has questionable viability, significant contamination, or has exposed bone or tendons, then options become more limited. The patient's goals and location also matter. Treating a person who is concerned with his/her appearance with an upper chest burn requires a more cosmetic graft since he/she may want to wear a V-neck sweater [Figure 2]. Patients without concern for appearance with a burn on the lower leg may not care if the graft is obvious. If the burn depth extends to muscle or a fascial excision is performed, then the loss of fat will cause depression. If the patient gains weight, the contrast between the normal fat-containing skin and the graft attached to the fascia becomes more noticeable [Figure 3]. Finally, patients with diabetes mellitus or peripheral vascular disease have a higher rate of graft loss[6,7], so improving the likelihood of graft take with a thinner meshed graft is more important than risking losing a more cosmetic, thicker graft. Like many procedures performed for burn care, there are essentially no studies that prove that one technique is better than any other. I present the following techniques based on more than 35 years of experience. Many other surgeons use different techniques, which will be covered in other papers in this Special Issue. I provide no rationale for my methods, other than they have worked well during my career. I provide several photographs illustrating the long-term outcomes of patients who have undergone these techniques.

Optimizing outcomes for small skin grafts

There are strategies to optimize the outcomes of skin grafts in small burns [Table 1]. One principle is promptly excising deeply burned tissue and applying an autograft directly onto the fat layer. There is no need to place a temporary allograft or dermal substitute to "prepare" the wound bed. We have excellent results with this technique, facilitating swift treatment and shorter hospital stays, enabling a quicker return

Table 1. Principles for optimizing outcomes for skin grafts

- Excise and graft on the same day
- Avoid fascial excisions if possible
- Meshed grafts always leave a meshed pattern
- Avoid small grafts within a larger area that is allowed to heal spontaneously. The mix of small grafts with surrounding hypertrophic scars is unsightly
- Use sheet STSGs for cosmetically important areas
- Thicker grafts shrink less than thinner grafts
- Use FTSGs for small areas (especially palms or face)
- User thicker sheet grafts for most functional/cosmetic areas (face, hands)
  - Use thinner grafts for less functional/cosmetic areas
- Grafts placed on loose skin contract more than when placed on tight skin
- Sheet grafts require more work (the reward is worth it)
  - All dermal elements must be removed (down to fat) to prevent inclusion cysts and skin bridges ("sponge skin")
  - Grafts should be checked on postoperative day 1 to remove seromas/hematomas
  - Reduce seams as much as possible (use wider dermatome)
  - Place seams to reduce contracture and follow esthetic units
  - Break up straight seams with darts
- Aggressive occupational/physical therapy and scar management are essential during the first 3-4 months, and optimally for up to a year for the best outcomes

STSGs: Split-thickness skin grafts; FTSGs: full-thickness skin grafts.

Figure 1. This small graft on upper chest was placed in an area with loose skin, so there was little resistance to prevent wrinkling.

to work or school for the patient. The primary objective should be to restore the injured site as closely as possible to its original, uninjured state. Using a sheet (non-meshed) split-thickness skin graft (STSG) instead of a meshed autograft always results in a more natural appearance[8]. With meshing, the meshed pattern persists for life [Figure 4]. Clearly, the wider the mesh, the more obvious the meshed pattern, though even a 1:1 meshed graft leaves a noticeable pattern. The other principle is that thicker grafts tend to shrink less than thin grafts[9]. Thicker grafts demonstrate greater resistance to contraction to a greater extent than thin grafts, which is particularly advantageous for small areas, such as palms, where full-thickness skin grafts (FTSGs) prove highly effective[10]. For larger areas, unmeshed sheets of STSG yield excellent outcomes. Thicker STSGs should be used for more functional areas, such as hands or face. When covering

Figure 2. A sheet graft placed on the upper chest of a young girl. The skin was harvested by a 6-inch-wide dermatome so that one piece could be used for the entire chest. The child will feel comfortable wearing a V-neck shirt or sweater.

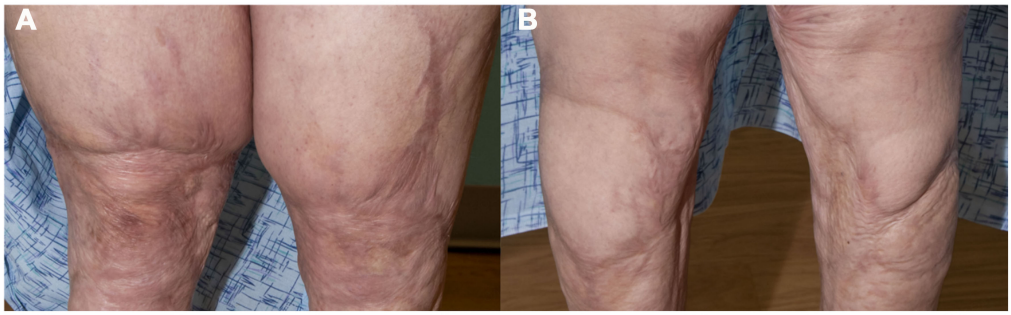

Figure 3. As a child gains weight, the difference between the normal skin and the fascial excision becomes more noticeable. This child is 14 years post-burn injury. Due to the depth of injury, her lower legs were grafted on muscle. The thighs were not injured. One can see that the upper thighs have gained weight with the excess fat, creating an obvious step-off to the lower leg grafts.

Figure 4. The mesh pattern in the arm graft is very noticeable. The hand has a sheet graft for comparison. The color differences are also very noticeable. There is no pigmentation in the palm, which makes the contrast even greater.

larger areas such as entire arms and hands, thicker pieces should be reserved for hands, with thinner grafts for the more proximal arms [Figure 5A and B].

Sheet grafts require different and more focused operative and postoperative care. While there is an emphasis on saving any viable dermal elements for meshed grafts, the opposite is true for sheet grafts. For instance, a key advantage of enzymatic treatments is that they do not remove viable dermis[11]. Saving viable tissue is appropriate for meshed grafts, but it is a problem for sheet grafts. If any dermal adnexa is left below the sheet of skin, inclusion cysts and skin bridges that collect debris will form. These "sponge-skin" deformities will detract from the cosmetic outcome[12]. The pits and bridges must be debrided to improve the outcome. Excision must be taken down to the fat and all dermal elements must be removed to prevent these problems in sheet STSGs. While there is a hesitancy to not graft on fat, the outcomes are excellent [Figure 4, Figure 5A and B]. Any barrier that prevents imbibition of nutrients from the wound bed to the graft leads to loss in that area. The graft should be checked on postoperative day 1 and any fluid beneath the graft should be drained. On day 1, even massive hematomas can be removed, and the graft will take. After day 1, the chances of graft loss increase. While more work, the results of sheet grafts can be excellent.

Another important consideration is how and where to place the seams between sheet grafts. Every seam can be compared to an incision in normal skin. Seams will always be visible, so there should be an attempt to reduce their numbers and align them to make them less noticeable. One method of reducing seams is to use a wider dermatome to harvest larger pieces of skin. The use of a 6-inch dermatome permits harvesting skin that can cover many recipient sites with one large piece[13]. The 6-inch dermatome can often cover most or all of a dorsal hand burn [Figure 5A and B]. Any seam or edge of graft that is straight, as for any incision, will produce more tension as it contracts. Tension is linked to more scarring and contraction[14], so placing darts in any seam or graft edge reduces tension and scarring[15] [Figure 6A and B]. In addition, seams should be placed at the junctions of esthetic units of the face[16]. Finally, the best way to create a seam is to overlap the skin [Figure 6A]. Typically, when trying to abut the edges, there tends to be a wider gap that leads to a wider scar at the seam.

Recently, a great emphasis has been placed on reducing donor site morbidity[5,17]. While reducing any donor site morbidity is important, it should not be the primary goal of treating deep burns. There is no donor site morbidity when enabling a third-degree burn of the palm to heal spontaneously, ultimately leading to severe contractures. The best practice is to balance the needs of the recipient site with the potential scarring of the donor site [Table 2]. Most patients would rather have scarring on an upper thigh or back, as opposed to severe hand or facial scarring. There are strategies that reduce donor site morbidity while obtaining an optimal graft. STSG donor sites follow the same principle that hypertrophic scarring increases after being open for more than 2-3 weeks. One should harvest STSG as thick as possible, while enabling it to re-epithelialize within 2-3 weeks. The other strategy is to place donor sites in areas that are hidden or rarely seen. For a FTSG, the inguinal crease works well because there is a linear scar where the leg bends [Figure 7A]. The inguinal crease is typically concealed, except when wearing the smallest bathing suits. The lower abdomen is another viable option. Although skin can be taken just below the inguinal crease, donor sites from this area are quite noticeable and may cause patients to feel hesitant about wearing bathing suits [Figure 7B]. Some areas of the body have a lower risk of morbidity at the donor site for STSG, mainly because the donor skin is thicker. The back has been shown to scar less than the thighs[18]. In addition, areas that have more dense hair follicles will heal faster than areas that have less hair. The scalp, due to its high hair density, typically heals within 4-5 days and rarely results in scarring. However, excessive thickness in donor harvesting carries risks of alopecia and hair transfer. One must also be aware that very old people tend to lose hair and develop atrophic skin. These sites are at greater risk for delayed healing and scarring.

Table 2. Principles for optimizing outcomes for donor sites

• Conceal FTSG donor sites - inguinal crease, lower abdominal fold
• Balance STSG thickness to reduce graft shrinkage but allow the donor site to heal within 2-3 weeks
• Harvest donors in areas that can be covered (upper thigh, lower back)
• Avoid harvesting skin from cosmetically important areas if possible
• Back donor sites tend to scar less than thighs (due to the back having thicker skin)
• Scalp donor sites heal quickly, but obtaining large grafts is hard
• Scalp donor skin should have hair removed as much as possible to reduce foreign body reactions and hair transfer
• Match donor skin to recipient site ("wrap around face graft")
• Scar management is essential for donor sites, just as for skin grafts

FTSG: Full-thickness skin graft; STSG: Split-thickness skin graft.

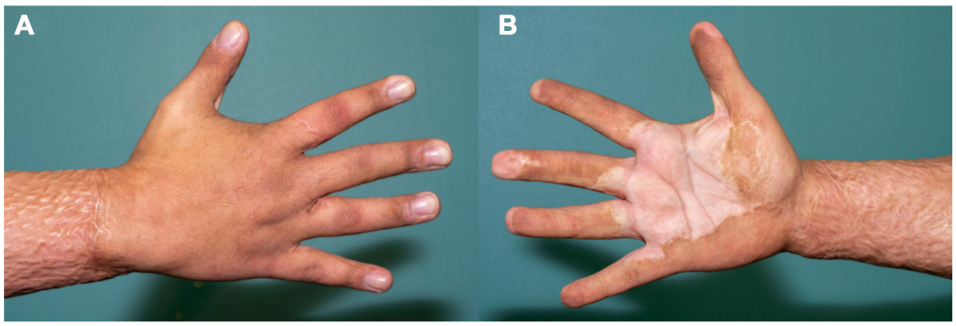

Figure 5. A patient with 31% third-degree burns to his face, arms, hands, and legs nearly 10 years ago. He underwent sheet grafts on his hands and face, and meshed grafts on the other areas. (A) The dorsal hand covered with one sheet of skin using a 6-inch-wide dermatome (except for the distal index finger); (B) The palmar side shows the obvious color difference due to the lack of pigmentation on the normal palm. The difference between the sheet STSG and the meshed STSG on the forearm is obvious. Even with extensive burns, placing sheet grafts on the hands is worthwhile despite the more proximal meshed grafts. The patient provided consent for the use of the picture. STSG: Split-thickness skin graft.

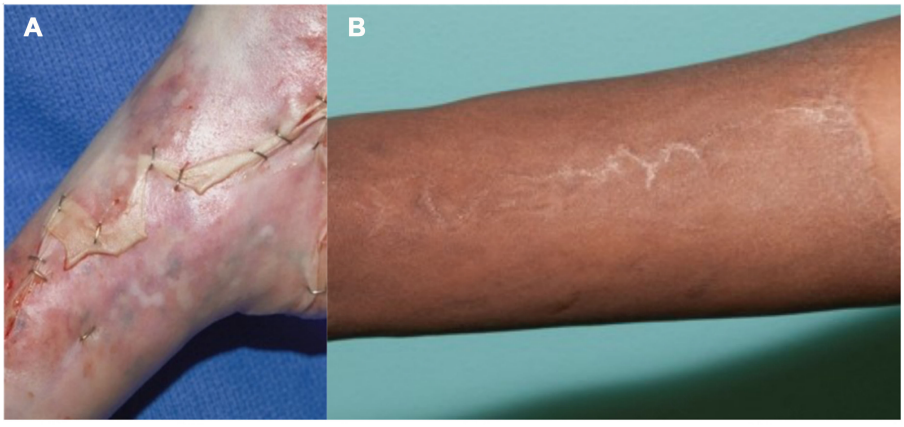

Figure 6. (A) When creating a seam between grafts, it is best to create "darts" that break up the straight line between grafts. Straight lines create tension, which leads to hypertrophic scarring. Darts break up that tension. Overlapping the grafts seen inferiorly on the left leads to the best seam. On the right, the upper part of the graft demonstrates how the grafts fold over when placed next to each other; (B) The seam on this forearm graft, taken more than 10 years after placement, demonstrates how a "zigzag" line avoids the hypertrophic scarring and contractures seen with most straight seams.

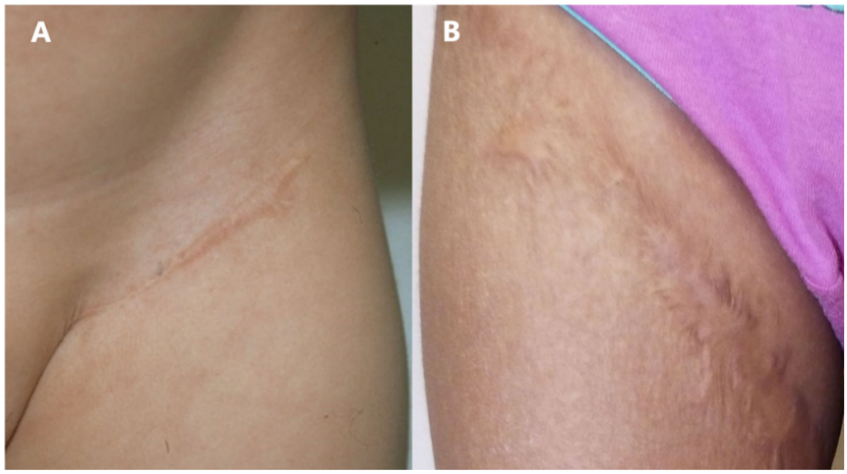

Figure 7. (A) A FTSG harvest at the inguinal crease leads to a line that follows the normal fold of the top of the thigh. This line is rarely noticeable; (B) A FTSG harvest below the inguinal crease is clearly visible below the panty line. This young woman may tend to avoid wearing a bathing suit because of the visible scar. FTSG: Full-thickness skin graft.

STSG donor sites often leave a slight texture difference and might have a different color than the surrounding tissue. Again, the safest strategy is to choose STSG donor sites in areas that might be hidden by clothing such as shorts. If the thigh is to be used, harvesting skin in a circumferential fashion at the upper thigh, from lateral to anterior to medial, will result in a donor site that can be hidden with shorts [Figures 8A and B]. The classic harvest down the lateral thigh will tend to be more exposed. The lower back is another site that is easily covered [Figure 8C]. One should try to avoid harvesting skin from the upper chest, back, or any other area that is typically exposed to the public [Figure 9].

Color match is another factor that must be considered for skin grafting. Skin grafts that are harvested above the clavicle tend to be a different color than skin from the lower body. A STSG harvested from the thigh and placed on the face will always be a different color [Figure 10A]. The scalp is a better color match for the face [Figure 10B]. Scalp donors take a significant amount of work since it is best to remove any remaining hair by scraping it off from the dermal side (never the epidermal side) with the back of a forceps. The important issue to remember is that the noticeable difference lies in the contrast between the color of normal skin and the graft. A small graft of a different color on the face is very noticeable, but replacing the entire face with a different-colored graft is not noticeable. Finally, many grafts tend to be darker than the surrounding skin [Figure 4, Figure 5A and B]; while it is not clear why there are different colors, over a year or years, pigmentation matching tends to improve. While we know a significant amount about the factors that regulate pigmentation, we have little control over its outcome. Patients are warned to be careful with sun exposure, but while creams that lighten or darken skin color are available, they rarely lead to a color that matches the surrounding skin[19].

Improving outcomes in important functional and cosmetic areas

There are special areas where extra care should be used to optimize outcomes - the hands and face. Both sites are almost always exposed to the public, so the focus should be on producing the best outcomes in those areas. Most hand burns involve the dorsal aspect, so a 6-inch-wide piece of skin can be used to cover most of the hand and minimize any seams [Figure 5A and B]. If there needs to be a seam, place it at the base of fingers. Palm burns are typically covered with FTSGs, but occasionally, the entire palmar side is burned. Large sheet STSGs do work well to cover the entire palm. When the burn involves the entire hand, coverage becomes more difficult [Figure 11A and B]. Try to cover the palm and dorsal hand with one sheet for each.

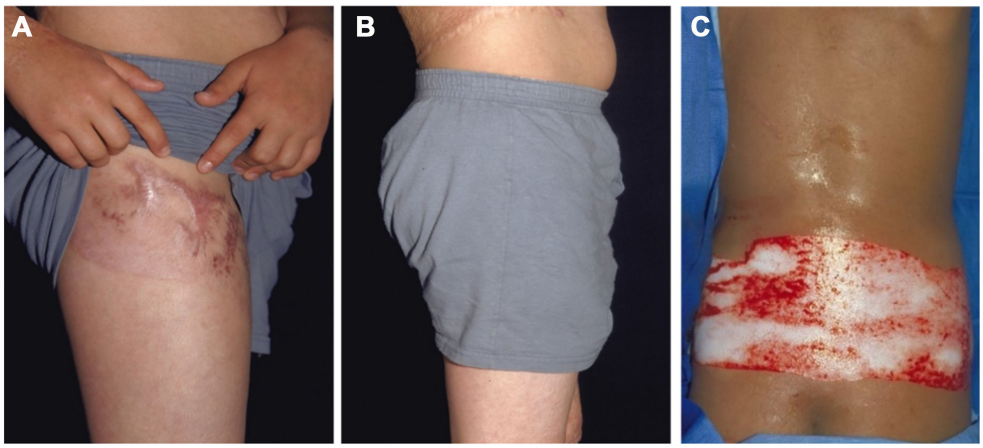

Figure 8. (A) A donor site harvested in a circumferential fashion at the upper thigh can easily be hidden with shorts (B); (C) the lower back is an excellent area for a donor site, especially in children. It can be covered with shorts and the back tends to scar less than other areas.

Figure 9. This donor site of the upper chest was taken because it was near the recipient site. It was placed in an obviously cosmetic area that would be seen with any opening of a shirt or V-neck. A site in the upper thigh or lower back would have been a much better choice.

For the fingers, wrap grafts circumferentially around the fingers. The best option is to have seams on the fourth webspace for the fifth and ring fingers, and the second webspace for the index and middle fingers. The seam on the ulnar side of thumb works well. It is essential for all skin grafts to have aggressive occupational/physical therapy support since contractures will occur if just relying on grafting alone. Pressure garments and silicone also help. One must remember that burns, especially skin grafts, get redder and thicker for 3-4 months before fading over the next several months. Complete maturation may take longer than a year. It is during this prolonged period when aggressive occupational/physical therapy and scar massage are essential to optimize outcomes.

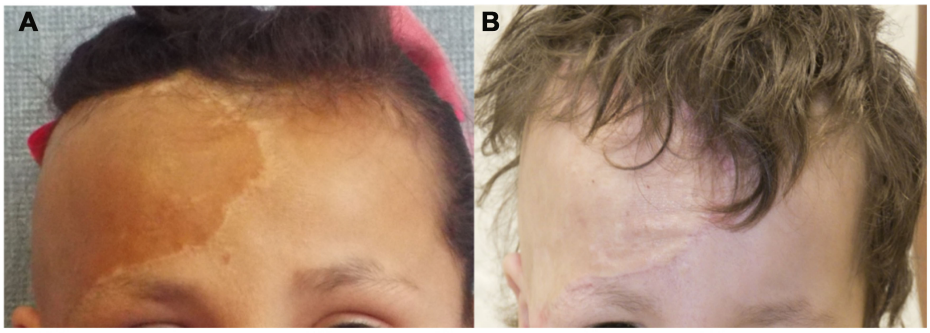

Figure 10. (A) This STSG graft to the forehead was harvested from the thigh. Skin harvested below the clavicle is much darker than skin harvested above it; (B) This scalp donor site has a much better (although not perfect) color match. STSG: Split-thickness skin graft.

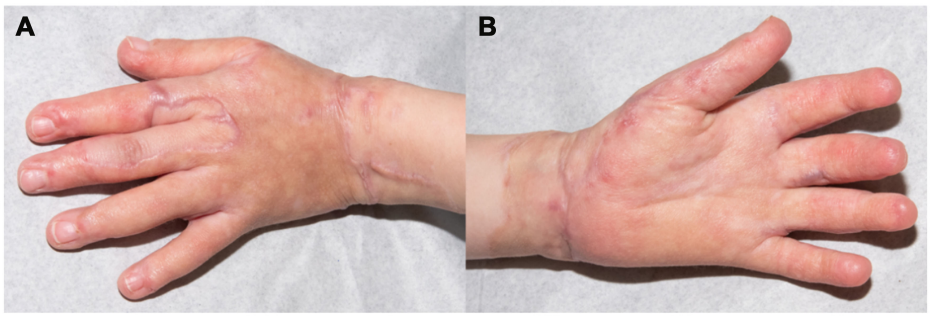

Figure 11. A circumferential hand burn (sparing part of the middle and index fingers) of a child falling into an incompletely extinguished campfire. The hand was grafted immediately on fat within a few days of injury with a large 6-inch-wide sheet STSG harvested from the back. The graft was wrapped around the ulnar side of the hand as one piece from the palm to the dorsum. The entire palm is covered with autograft, while the dorsal graft covers all but the dorsal middle finger and a small part of the index finger. At six months after injury, both grafts on the dorsum (A) and palm (B) have an excellent functional and cosmetic outcome. The patient's guardian provided consent for the use of the picture. STSG: Split-thickness skin graft.

Treatment decisions about faces are also very complicated, but good grafts can lead to excellent results. For very small but deep burns, however, it is best to allow the wound to heal without grafting. Small grafts in the face will always have color and texture differences from the rest of the facial skin, so they are quite ugly. While the treatment decision is difficult, it is often better to allow those areas to heal with a scar and plan for future reconstructive surgery. For larger areas that will need a graft, it is best to use the scalp as a donor site if possible [Figure 10B]. The donor should be harvested as thick as possible without causing alopecia. A significant problem with sheet STSGs from the scalp is from the remnant hair and hair follicles. Leaving the hair in the graft can result in hair transfer, which is a problem when in an area that lacks hair. The scalp should be shaved, and after harvesting, most of the hair can be removed by scraping the dermal side. In addition, hair fragments left under the graft will lead to inclusion cysts, so it is useful to eliminate as much hair as possible. When dealing with a third-degree burn covering the entire face, the scalp is not the best option. First, it is very difficult to obtain enough skin to cover an entire face in an adult. Getting wide enough donors is not easy, and using narrow grafts often leaves a lot of prominent seams. Second, since the entire face is viewed as a unit, one piece from a distant site is not very noticeable due to the absence of contrasting skin tones nearby. There should be an effort to place seams at the boundaries of esthetic units (lateral to the eyes, nasolabial folds, coursing down from the commissures). To minimize seams, I have developed a technique where skin is harvested in a circular or "U-shaped" fashion. The graft can then be wrapped around the entire face, leaving only one seam[20-22] [Figure 12A, B, and C]. Face grafts require careful attention due to their tendency to develop contractures. The most common early problem involves

Figure 12. A patient with 31% third-degree burns to his entire head, face, arms, hands, and legs nearly 10 years ago. He underwent sheet grafts on his hands [Figure 5] and face, with meshed grafts in the other areas. He had a "wrap-around" face graft (A, B, and C), with some areas of loss to the right side of the face (B). He had a recent right neck contracture release with a graft under the angle of the jaw (B). The "wrap-around" face graft leads to an acceptable outcome despite requiring separate grafts to most of the scalp. The seam is seen coursing inferiorly from the right commissure when looking straight at (A). There are no seams on his left side (C). The patient provided consent for the use of the picture.

eyelid contractures, but mouth/commissure contractures also occur. We use hard and soft facemasks, along with silicone patches, to help with hypertrophic scarring. Creating traction to counteract graft shrinkage by taping areas such as the eyelids also helps. Again, prolonged, aggressive therapy and scar management are essential to optimize the outcomes of face burns.

Optimizing outcomes of large burns

The functional and cosmetic outcomes of burns are dependent on several factors. Clearly, very deep burns, especially fourth-degree burns, are more difficult to deal with. Small areas of exposed bone or tendon can often be covered with dermal substitutes, and when vascularized, they can be grafted. Areas of exposed skull can have the outer table burred to allow for granulation tissue growth and eventual grafting. Various flaps can also be used, but this paper will not cover flaps. Obviously, patients with massive burns will not have enough donor skin to use sheet grafts, so compromises must be made. The strategy of promptly removing visibly deep burns (within a few days) is important, as it helps suppress the hypermetabolic response[23]. Some of the strategies described earlier can still be used to improve outcomes in more functional or cosmetic areas. For instance, we often use sheet grafts for the hands and faces of patients with burns > 80% TBSA. The rest of the areas are covered with widely (4:1) meshed grafts. One of the problems we had in the past was the delay in re-epithelialization of the interstices of wide mesh. We have found that spraying autologous epidermal cells (RECELL®, Avita Medical, Valencia, CA) fills the interstices rapidly, and appears to accelerate the healing of the donor sites. (A more expansive description of RECELL® will be covered in another paper in this review.)

When all of the donor skin has been utilized, the remaining excised burn should be covered with a temporary "skin". We have found that allograft does not work as well as in the past. Allograft tends to degrade after 2-3 weeks, leaving granulation tissue. A better option is to cover the wound with a dermal substitute. While we have used Integra® (Integra Life Sciences, Princeton, NJ) in the past, we currently use NovoSorb® BTM (PolyNovo North America LLC, Carlsbad, CA), which is a polyurethane foam covered with a polyurethane surface as a temporary covering. The product takes around two weeks to vascularize, but it can also develop a prolonged, quiescent state that protects the underlying tissue without signs of inflammation. As an example, it persisted without infection on the face for a patient with 90% TBSA burns

for 73 days until skin was available for grafting[20]. After vascularization, NovoSorb® BTM can be grafted with sheet grafts, or wide mesh with RECELL® spray. For the burns > 85%-90% TBSA, we will also cover the matrix with 6:1 meshed autograft, cultured epithelial autografts, and RECELL®[24]. Our outcomes for the massive burn have been decent[25]. While patients survive, scarring is still a major sequela. Many other papers in this Special Issue will cover the use of the various newly available products.

CONCLUSION

There are many strategies using relatively inexpensive and standard equipment that can optimize outcomes in burn patients. To optimize re-epithelialization, maintain a moist environment to shorten the time to wound closure and reduce hypertrophic scarring in partial-thickness burns. Patients can have early excision and grafting on the day of excision with excellent results. Sheet split-thickness skin grafts always have better appearances compared to meshed grafts. Thicker grafts contract less than thin ones and should be prioritized for more cosmetic areas, such as the hands and face. Compromises must be made when dealing with massive burns, but decent outcomes are possible. As more patients with massive burns survive the effort, the focus should be on optimizing their cosmetic and functional outcomes.

DECLARATIONS

Authors' contributions

The author contributed solely to the article.

Availability of data and materials

Not applicable.

Financial support and sponsorship

None.

Conflicts of interest

The author declared that there are no conflicts of interest.

Ethical approval and consent to participate

Since this paper does not involve research, institutional review board (IRB) approval is not required by the institution (Shriners Children's Northern California). Written consent was obtained for pictures with identifying features [Figures 5, 11, and 12]. Due to de-identified historical medical records, obtaining informed consent is not feasible.

Consent for publication

Written consent was obtained for pictures with identifying features [Figures 5, 11, and 12].

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