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Case report

REVIVING CRANIAL OUTER TABLE PERFORATIONS AS A MODERN INNOVATION FOR COMPLEX SCALP AVULSION INJURIES RECONSTRUCTION: A CASE REPORT

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Abstract

Introduction: Scalp avulsion injuries can present a tremendous challenge for both the patient and the surgeon. The absence of periosteum can limit the reconstruction options. Various surgical techniques are available for scalp reconstruction, including skin grafting, microsurgical scalp replantation or free flaps. A cranial outer table perforation is also a potential treatment since we activate the body's natural healing processes and within a matter of days the defect is gradually repairing with granulation tissue on which we can use skin grafts for further reconstruction.

Case Report: A 52-year-old patient was brought at our emergency center, due to an injury that occurred as a result of hair entrapment in high-speed rotatory devices, such as agricultural machine. Since the patient refused a potential treatment using free flaps, and microsurgical scalp replantation was not possible due to the condition of the avulsed scalp segment, we made transcortical holes in the outer table of the cranium up to the level of diploe for reconstruction of this defect.

Discussion: For individuals with scalp defects as a result to a trauma, a carefully planned multidisciplinary approach is required. It is crucial to have a comprehensive understanding of scalp anatomy, wound healing principles and physiology. Every reconstructive option should be taken into consideration.

Conclusion: Despite the significant advancements made in the reconstructive field, we are often faced with situations where we have to rely on a valuable historical medical technique. The modern reintroduction of cranial outer table perforations offers a bold, yet practical solution.

Keywords: scalp avulsion injuries, reconstruction, transcortical holes in the outer table of the cranium, skin grafts, wound healing, reconstructive ladder

Introduction

Scalp avulsion injuries with severely damaged periosteum although rare, remain one tremendous challenge in plastic and reconstructive surgery. In such occasions when they occur, they have the potential to be life-threatening and are usually accompanied with massive scalp defects. The most common cause for the occurrence of these injuries is when long hair gets entangled in high-speed rotatory devices, such as those found in agriculture, thus resulting with the scalp being completely torn away[1]. A number of discoveries and innovations have been made, firstly to prevent these types of injuries, and secondly to reconstruct the defect. There are multiple approaches available for scalp reconstruction, which may include skin grafting, microsurgical scalp replantation or free flaps, depending on the specific situation. Each of these approaches demands a thorough knowledge of the scalp anatomy[2]. The real challenge comes with the absence of the periosteum, since it narrows the options for reconstruction and often necessitates vascularized free flap as other methods may prove ineffective. In such cases, when the periosteum is ravaged, and the replantation is not possible, in addition to the aforementioned surgical techniques, another option for treatment is making transcortical holes in the outer table of the cranium and within a few days, the holes begin to fill with granulation tissue, gradually repairing the defect. The practice of using cranial outer table perforations to treat scalp avulsions that affected the underlying periosteum dates back many centuries[3]. Conversely, with the advent of newer alternatives, such as the invention of free flaps and microsurgical scalp replantation, the use of this technique has decreased over time. Our team decided to reintroduce this technique when a 52-year-old female was admitted to our emergency department with a large scalp injury resulting from a hair entrapment in an industrial machine and since there was no possibility for a microsurgical replantation and no informed consent for a free flap was obtained by our patient, this was the optimal treatment. This decision represents an innovative approach to modern medical practice, one that it is based on a complete knowledge of the evolution of surgical techniques and deep appreciation for history.

Case Report

A 52-year-old female arrived at our emergency department with a significant scalp injury due to a hair entrapment in an industrial machine with rotating features (Figure 1). Injuries included a total scalp avulsion with anatomical borders that were anteriorly above the eyebrows and laterally and posteriorly by the neck, linear fracture on the occipital bone, amputated right ear, and lacerations on the right side of the face. A part of the periosteum in the parietal area around 10 x 10 cm was severely destroyed. Scalp reconstruction with free flaps typically requires the use of recipient vessels with adequate size and flow. The patient presented with severe damage to the superficial temporal vessels, which are the most commonly used vessels for scalp reconstruction due to their proximity and accessibility to the scalp. Necessary examinations including blood analysis and CT scan of the head and neck were conducted. The patient was admitted to the intensive care unit and was intubated, got antibiotics, fluid resuscitation, and blood transfusion (Figure 2).

Fig. 1. 52-year-old female with severe scalp injury due to hair entrapment

After stabilizing her condition and carefully evaluating the specific circumstances of the patient, taking into account critical factors such as wound location and extent, age of the patient and overall health, our surgical team evaluated several approaches for achieving optimal outcome including free skin grafting, microsurgical scalp replantation and free flaps. Furthermore, the team also explored the possibility of combining multiple procedures. Although scalp replantation was a potential treatment option, it was not feasible due to the condition of the avulsed scalp segment and the absence of appropriate blood vessel for potential microvascular anastomosis since the superficial temporal vessels were completely destroyed. Not obtaining informed consent by the patient for performing a free flap, narrowed the options even further. Another promising approach was creating transcortical holes in the outer table of the cranium. By doing this, the body's natural healing processes are activated and within a matter of days these holes become filled with a gradual and effective repair of the defect. Following the formation of a new granulation, skin grafting technique that involves transplantation of healthy skin to the affected area can be used to cover the tissue and promote further healing and restoration of the damaged area. By combining the creation of granulation tissue using transcortical holes in the outer table of the cranium and careful application of skin grafts, our surgical team reached a decisive conclusion about the combination of these two techniques as the optimal treatment for our patient.

Fig. 2. The patient was admitted to the intensive care unit

The patient was then taken to the operating room and the initial management involved cleaning with massive irrigation with saline solution 0.9%, hydrogen 3%, and betadine 10% and debridement of the wound to remove any foreign bodies and devitalized tissue. Local soft tissue flaps from the residual epicranial tissue were then reconstructed to cover as much as possible of the deperiosted bone (Figure 3). The lacerations on the right side of the face were sutured with a simple interrupted suture. Finally, the wound was covered with Vaseline-gauze dressing.

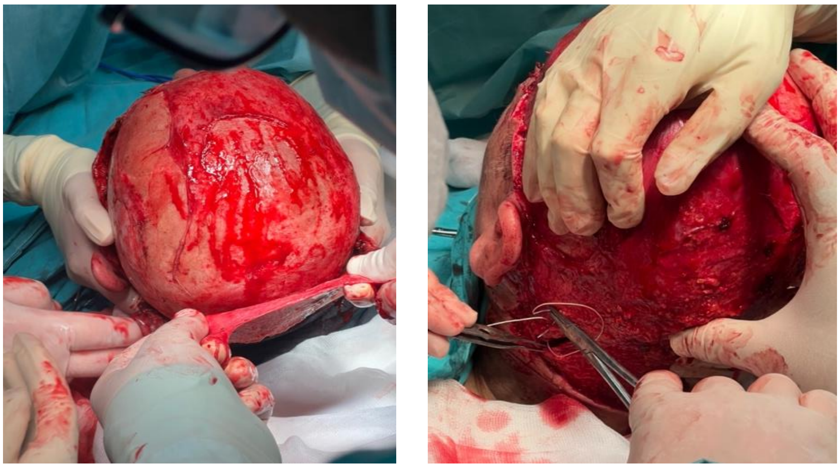

Fig. 3. Local soft tissue flaps from the residual epicranial tissue were then reconstructed to cover as much as possible of deperiosted bone

Three weeks later, our patient underwent surgical treatment that was performed under general anesthesia. An autologous split-thickness skin graft was harvested from the patient's posterior part of the thighs using an electric dermatome, which was then meshed and it was used to cover the granulated tissue. The split-thickness skin graft was meshed to get a bigger volume of the graft itself and was fixed using a stapler. On the parts that were not covered with periosteum, a trepanation to the diploe was performed to stimulate granulation tissue over the deperiosted bone for the next surgery. The outer cortex was fenestrated using the Misonix BoneScalpel, which is a cutting-edge surgical tool that uses ultrasonic energy to make precise bone cuts, minimizing damage to surrounding soft tissues[4]. A total of seven burr holes were made with dimensions of approximately 1.5 cm x 1.5 cm and positioned at least 3 cm away from the nearest tissue. Each of these burr holes was covered with Surgicel, an oxidized cellulose polymer that has hemostatic, bactericidal, and vasoconstrictive properties[5]. A gauze impregnated with Vaseline and gauze soaked in a NaCl 0.9% solution were applied to cover the wound. Following the procedure, the patient was administered a combination of antibiotics, fluids, pain relief medications, and gastroprotective therapy (Figure 4).

Fig. 4. Misonix BoneScalpel used for precise fenestration, an autologous split-thickness skin graft was meshed and used to cover the granulated tissue

During the first change of the dressing, the Surgicel was removed, thorough irrigation with a hypotonic solution was performed and the wound was covered with a Vaseline gauze, following a gauze soaked in NaCl 0.9%. This type of occlusive dressing was applied every two days during the first two weeks. Granulation tissue emerged from the burr holes and started spreading and filling the defect after the first week (Figure 5 and 6). After that, the patient was discharged from hospital and was provided with information about home regimen including instructions on how to monitor any signs of infection, as well as instructions regarding management of their dressing. After discharge, the patient had follow-up appointments at our outpatient clinic two times per week for occlusive dressings changes. As they lived in another city, some dressing changes were later done at health facility near the patient's house.

Fig. 5. Granulation tissue starting to fill the burr holes two days postoperatively

Fig. 6. One week after the cranial outer table perforation

Two months after trepanation, the patient underwent a second surgery in which the granulated tissue that emerged from the burr holes was covered with a meshed split-thickness skin graft, which was harvested with an electric dermatome from the patient's anterior part of the thighs. The graft was fixed using a stapler after which the patient's wound was covered with the same type of occlusive dressing as before. Subsequent to hospital release we scheduled twice-a-week follow-up appointments at our outpatient clinic, during which we would replace the dressings. The term "*locus minoris resistentiae*" refers to a site or area of the body that has decreased resistance or vulnerability to infectious agents[6]. In this case, due to the injury sustained by our patient, the scalp has become a *locus minoris resistentiae*, increasing the likelihood of infection. As a result, in the following few months during a dressing change, graft lysis was noted. A wound swab was obtained using Levine's technique and sent to the microbiology department for analysis[7]. The analysis came back positive for MRSA (*Methicillin-resistant Staphylococcus aureus*). As the microorganism exhibited sensitivity to vancomycin, treatment was started. A gauze soaked with vancomycin diluted in saline solution was applied as a dressing. Despite facing challenges, including skin graft lysis due to the infection, our primary goal of successfully covering the exposed periosteum was achieved (Figure 7).

Fig. 7. Skin graft dissolves due to infection

As treatment progressed, our patient transitioned to using Octenisept, a potent wound antiseptic and weeks later, we were thrilled to witness the final outcome, which not only met but exceeded our expectations, providing complete coverage on the scalp. Based on the outcome achieved, we confidently report successful culmination of the treatment for this particular case. Although the road was challenging, our dedication to our patient's well-being helped us ensure a positive outcome (Figure 8 and 9).

Fig. 8. Nine months after injury

Fig. 9. One year after injury

Discussion

Reconstruction for scalp avulsion injuries can present a formidable challenge for plastic and reconstructive surgeons. They require serious attention as neglecting them can result in severe consequences, including long-lasting impairment, disability, or even death. Successful treatment of scalp avulsion injuries requires a comprehensive understanding of human anatomy, physiology, and various treatment approaches. The scalp covers the skull and thus it provides protection to the brain. Serving as a crucial anatomical barrier against external trauma, the scalp plays critical role in minimizing the risk of injury. The anatomy of the scalp is composed of five layers, beginning with the skin, which contains hair follicles, sweat and sebaceous glands and its thickness measures up to 8 mm. The next layer is subcutaneous tissue containing a rich network of blood vessels which provide nourishment and nerve endings. The third layer of the scalp, known as the *galea aponeurotica*, is a firm and fibrous sheet of tissue and as such it prevents any stretching by securely attaching to dense subcutaneous connective tissue layer. The loose areolar tissue is the subsequent layer and it allows all the aforementioned layers of the scalp to slide over the skull. Periosteum is the fifth and the outermost layer of the skull bone[2,8]. The presence of periosteal layer in scalp avulsion injuries significantly impacts the treatment approach. If present, it simplifies reconstructive options such as free skin grafts, acellular dermal matrix, and secondary intention healing. Another crucial aspect of choosing the right treatment involves a thorough comprehension of the wound physiology and the phases of the healing process[9]. In addressing scalp defects, reconstructive ladder offers a practical framework that can be applied to achieve optimal outcomes, depending on the nature of the defect[9]. The ideal approach for reconstruction includes several factors. Firstly, the reconstruction approach should be straightforward and easy. Secondly, it should be durable, with ability to withstand stress and resist potential complications. Finally, the reconstruction should be aesthetically pleasing, ensuring the patient’s cosmetic concerns. Managing scalp avulsion injuries can present a significant difficulty, especially when there is a part of the bone that it is lacking periosteum, and you have compromised surrounding blood vessels. Throughout the years, various treatment options for scalp avulsion injuries have emerged. The choice of a technique depends on factors like injury extent, depth, initial assessment, risks, informed consent, personal considerations, and the patient's overall health. Surgical treatment of scalp avulsion injuries typically involves initial debridement and irrigation of wound, followed by reconstruction with flaps or grafts. Free flaps are a type of tissue graft that includes skin, fat and/or muscle along with their associated blood vessels, that are detached from the donor site and reconnected to the blood supply of the recipient site using microsurgical techniques. The most commonly used vessels are superficial temporal vessels, which are closest to the scalp and are easily accessible. However, due to their small caliber, they are susceptible to spasm, which can lead to flap compromise. Other potential recipient vessels include facial artery and vein, superficial thyroid artery and vein, internal maxillary artery and vein, external and internal jugular vein. All of these vessels are located further away from the scalp, which certainly makes the situation more complex and carries bigger risks. Knowledge of vascular anatomy is essential for selecting the appropriate recipient vessels for successful free flap. Free flaps that have been used in scalp reconstruction include *latissimus dorsi* (LD) free flap as the most frequently used flap in scalp reconstruction, *rectus abdominis* free flap, radial forearm, anterolateral thigh (ALT), omentum, subscapularis and serratus muscle[10].

Latissimus dorsi muscle free flap is widely regarded as optimal choice for total scalp reconstruction, owing to its ability to provide extensive coverage, excellent pliability and a long dependable vascular pedicle, which has made it the most frequently utilized flap[10]. This procedure involves harvesting *latissimus dorsi* muscle from a patient’s back along with a segment of skin and subcutaneous tissue and transplanting it onto the scalp, and as such it requires specialized surgical expertise, as well as careful patient selection, but can achieve highly satisfying results in the hands of experienced surgeons.

Radial forearm flap can also be used for the reconstruction of scalp injuries. This procedure involves harvesting a segment of tissue, including skin, subcutaneous fat and fascia from the forearm, along with its associated blood vessels and transferring it to the scalp. Its dependable and long pedicle anatomy simplifies dissection and harvest and has a relatively low rate of donor site complications[10]. Although the radial forearm flap has several benefits as a reconstructive technique, it may not be suitable for large scalp defects due to insufficient soft tissue coverage.

Anterolateral thigh flap (ALT) is a multipurpose type of flap, that offers several advantages. It can be harvested as an adipocutaneous, fasciocutaneous or chimeric flap[12-14]. With ALT flap, the *vastus lateralis* muscle or the *tensor fascia lata* muscle can be harvested and with that it can provide additional coverage[12-15]. Although ALT has numerous advantages, its effectiveness may be limited for extensive scalp defects due to its restricted width. To elaborate further, ALT flap may not provide sufficient coverage for larger areas of the scalp, making it unsuitable for such cases. Each flap technique is linked with significant drawbacks, which can vary[15]. These disadvantages include a short pedicle length, prolonged postoperative recovery, vessel caliber mismatch and a high potential for donor-site morbidity. It is important to weight the benefits and drawbacks of each technique carefully before choosing the appropriate method for reconstruction. Free flaps have made a significant advancement in the past decade and even though they provide a quicker solution, there are situations where the use of free flap cannot be utilized and personal factors of the patient interfere. In such scenarios, this technique can be a viable alternative due to its shorter operating time, simpler equipment and greater safety measures.

Microsurgical scalp replantation is a complex surgical procedure that involves reattachment of a partially or completely amputated scalp. The procedure utilizes microsurgical techniques to reconnect the blood vessels, nerves and tissues of the scalp to restore blood flow and promote healing[16]. Replanted scalp can survive and regrow hair if blood supply is restored successfully. It is a viable option for patients with these injuries if the detached scalp is in good condition. Unfortunately, due to the severe damage of the detached scalp, microsurgical scalp replantation was not an option in our case.

Skin grafting is a surgical procedure in which a section of healthy skin is transplanted from a donor site of the body to another recipient side that has been damaged. Grafting may not be the preferred method compared to flap closures, but it still yields satisfactory cosmetic outcomes, particularly in situations where the use of flaps is limited. There are two main types of skin grafts: split-thickness skin grafts (STSG) and full-thickness skin grafts (FTSG). Split-thickness skin grafts (STSG) are composed of the epidermis and the superficial part of the dermis[17]. STSG are used for covering large areas of the body. In contrast, FTSG involves removing the entire thickness of skin from the donor site, including the dermis to be transplanted to the recipient site. This type of graft is preferred for smaller areas, where optimal cosmetic outcomes are crucial. Compared to full-thickness skin grafts, split-thickness skin grafts can thrive on relatively avascular areas where an FTSG would usually be unsuccessful.

Although the technique of using cranial outer table perforations to treat scalp avulsions that affected underlying periosteum dates back many centuries, it still holds significance in modern times. To achieve optimal results, surgeons often use a combination of various techniques. This case report serves as a powerful reminder of the importance of flexibility, creativity and history in the face of complex surgical cases.

Conclusion

Scalp injuries with avulsion of the skin and underlying bony defects present complex challenge. Surgical intervention with debridement, trepanation and split-thickness skin grafting can result in successful wound healing and satisfactory outcomes. In these modern times, reintroducing the use of cranial outer table perforations to treat scalp avulsions is a bold, but very practical move. We were able to use the combination of formation of granulation tissue through creation of transcortical holes in the outer table of the cranium, followed by a precise application of skin grafts to fulfill the specific needs of our patient and achieving positive outcome. Close monitoring and postoperative wound care are essential to prevent complications and achieve optimal results. By building upon the rich tradition of medical innovation and discovery, surgeons can continue to push the boundaries and offer their patients the most effective and personalized treatments available.

Conflict of interest statement. None declared.

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