

Surgical strategies for cutaneous neoplasm of the scalp

State of art



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Surgical strategies for cutaneous neoplasm of the scalp: State of art

AIM: Scalp reconstruction has always been a challenging task, in particular after oncological demolition and this article gives an overview on the state of the art in scalp reconstruction strategies.

MATERIAL OF STUDY: We elaborated a systematic algorithm for scalp reconstruction based on location and size defects, presence or absence of periosteum, bone involvement, the quality of surrounding scalp tissue, the presence or absence of hair, location of the hairline, patient comorbidities and different procedures commonly used in plastic surgery.

RESULTS: Our algorithm allows plastic surgeons to perform scalp reconstruction after the most devastating of defects.

DISCUSSION: Successful reconstruction of the scalp requires careful preoperative planning and detailed knowledge of scalp anatomy, hair physiology, variety of available local tissue and plastic surgery procedures as well as synthetic substitutes or products provided by tissue engineering.

CONCLUSION: However, the challenge today is to do so with excellent cosmetic results.

KEY WORDS: Scalp reconstruction, Skin carcinoma

Introduction

Scalp reconstruction has always been a challenging task, in particular after oncological demolition. Diverse and complex set of scalp defects can be distinguished mainly in two types. In case of small-to-moderately sized defects in patients with good general health full closure

is achieved easily. Aesthetic aspects, including preservation of eyebrow symmetry, hairline as well as avoidance of alopecia, are the challenge in those cases. Besides, large defects in patients with poor general performance status requires full closure that is the ultimate and challenging goal.

Tumours attributed to actinic damage show a constant rise in incidence, and the exposed location of the scalp leaves it as one of the primary regions for skin cancer ¹. Rarer malignancies are soft-tissue sarcomas, primary adnexal cancers, and secondary malignancies ². Because of the apparent location of the tumour, patients usually are seen at an early stage of the disease, when simple resection with primary closure is possible, leading to an excellent prognosis.

The oncological radicality should be pursued especially in large infiltrating tumors, although the extent of the residual defect after excision may result in technical difficulties for the reconstruction.

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Although the reconstructive challenges increase exponentially with local tumour advancement, the modern methods of reconstructive surgery allow for radical resection and reconstruction of virtually any extent of scalp tumour. The limitation to this rule more strongly depends on invasion into deeper structures than on the extent of infiltration of scalp tissue by the tumour³. Scalp reconstruction after malignancies may be suboptimal when insufficient oncologic radicality is used⁴, when inadequate reconstructive procedures are selected leading to prolonged recovery and/or unstable scars, and when patients delay consultation until the tumour has reached extensive dimensions.

Surgical excision with adequate margins is the standard treatment for scalp malignancies. For instance, it has been evidenced that for node-negative, primary scalp melanoma, subperiosteal resection can significantly decrease in-transit/satellite recurrence when compared with subgaleal resection⁵. Adjunctive treatments such as irradiation, chemotherapy, and immunotherapy have to be considered as adjuvant therapies or second-choice options if surgery is impossible or not desired^{9,10}.

Surgical treatment of scalp neoplasm requires a precise diagnostic evaluation. Clinical assessment is often sufficient to assess small lesions involving scalp superficial layers and leaving deep layers intact; this is clearly proved by the possibility to mobilize the lesion on the cranium. Larger lesions that show to be adherent to deep planes require a diagnostic imaging to define local and distant involvement. Once the diagnostic iter is completed, the more appropriate treatment modality can be selected, taking into account patient's age, condition and will.

ANATOMY OF THE SCALP

The scalp is defined as the anatomic area overlying the skull between the superior orbital rims anteriorly and the superior nuchal line posteriorly. Soft and hard tissues within this region are commonly divided into six layers: skin, subcutaneous tissue, galea, loose areolar tissue, calvarial periosteum (pericranium), and calvarial bone. The skin of the scalp is the thickest in the body, ranging from 8 mm thick in the occipital area and decreasing in thickness as one moves anteriorly and temporally (3 mm). It is attached by firm, fibrous septae that run through the subcutaneous to the underlying galea. The subcutaneous layer of dense connective tissue and fat binds the skin to the underlying galea. The subcutaneous layer contains the principal arteries and veins of the scalp, as well as the sensory nerves and lymphatics. Because of the fibrous septae, this layer is inelastic and firm. The blood vessels embedded in this layer bleed freely when transected presumably because they are less able to retract.

The galea aponeurotica is the tough fibrous layer of the scalp. It is extensive in its attachments and is a part of

the subcutaneous musculoaponeurotic system (SMAS) of the face. It connects the occipitalis muscle posteriorly with the frontalis muscle anteriorly and the temporoparietal fascia (superficial temporal fascia) in one temporal region with the same layer on the contralateral side. The loose areolar plane beneath the galea is composed of thin, avascular connective tissue and has been termed in various ways (innominate fascia, subaponeurotic layer, subgaleal fascia^{6,7}). This plane is easily dissected. The laxity of this layer contributes for the mobility of the scalp.

The innermost layer of the scalp, the pericranium, is densely adherent to the outer table of the skull. The pericranium contains a rich vascular network that allows it to serve as a recipient bed for skin grafts or as a flap. The scalp has a rich blood supply arising from four principal arteries and lesser contributing vessels. The occipital and superficial temporal arteries on each side are the main vascular afferents. Lesser contributions to the scalp are made by the posterior auricular artery, small branches of the external carotid artery, and the supraorbital and supratrochlear vessels. These vessels travel in the subcutaneous layer and form abundant anastomoses, such that the entire scalp can survive one major vessel⁸.

The scalp has multiple sensory nerves. The anterior portion of the scalp is supplied by the supraorbital and supratrochlear nerves. A branch of the second or third cervical nerve, the lesser occipital nerve, supplies the posterior scalp. The great auricular nerve provides sensation to the posterior auricular region, earlobe, and angle of the jaw. The temporal region receives sensory input from the auriculotemporal nerve, a branch of the mandibular division of the trigeminal nerve. This nerve can be found accompanying the superficial temporal artery just above the zygomatic arch.

SURGICAL STRATEGIES IN SCALP RECONSTRUCTION

When the lesion do not extend beyond the galea, the surgical excision is performed in the subgaleal plan (Fig. 1). In cases of deeper tumor extension and suspicious external cortical bone involvement, the external calvarium requires to be removed en block together with the lesion (Figs. 2, 3). More advanced tumors infiltrating the diploic bone require a full thickness calvarium demolition (Fig. 4). Therefore, reconstruction of the scalp depends on the structures missing.

Partial thickness defects

Coverage with a skin graft is usually only an option superficial to the temporalis muscle or if oncologic radicality allows for the periosteum to remain intact

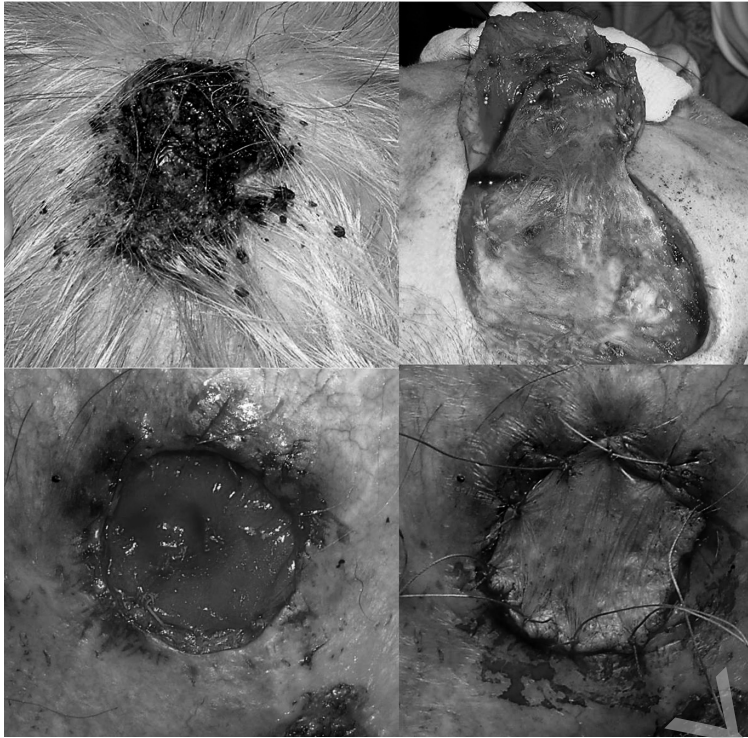


Fig. 1: Above left- preoperative view of a 70ys old male, affected by a basal cell carcinoma of the scalp; Above right- intraoperative view showing sub-galeal cancer excision; Below left- intraoperative view showing scalp defect after cancer excision and round block suture to reduce defect dimension; Below right- intraoperative view showing skin grafting of the scalp defect.



Fig. 2 Above left- preoperative view of a 51ys old female, affected by a relapsing squamous cell carcinoma of the scalp; Above right- intraoperative view after cancer excision and bone milling; Below left- scalp cancer after excision; Below right- early post operative view after reconstruction by cutaneous pedicled flap and skin graft.

(Fig. 1). Furthermore, skin transplants frequently result in unstable, depressed, and unsightly scars, which have to be rated as poor from both functional and aesthetic standpoints. The lesions are relatively small (from 2 to 5 cm in diameter). Hair transplantation may be required for secondary scalp reconstruction.

Full thickness defects

Full thickness defects are subject to necrosis and sequestration of dried exposed bone. Skin grafting is not a practicable option without intact pericranium. Thus, a more aggressive approach is required.

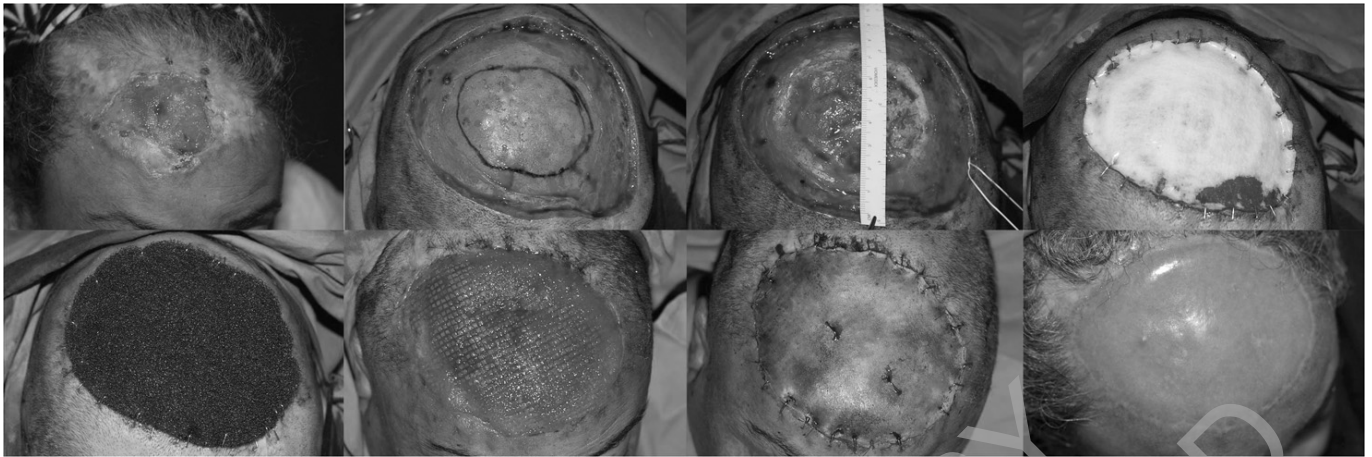


Fig. 3: Above extreme left- preoperative view of a 71ys old female, affected by a relapsing infiltrating basal cell carcinoma of the scalp with suspicious external cortical bone involvement; Above center left- intraoperative view showing wide tumor excision with 15 mm of surgical skin margins; Above center right- intraoperative view showing the defect after resection of the external cortical bone and round block suture with Gore-Tex CV-0 (W.L. Gore & Associates, Flagstaff, AZ, USA); Above extreme right- defect covered with a 10x10 cm Hyalomatrix® template; Below extreme left- defect covered with a polyurethane sponge applied on the Hyalomatrix® template; Below center left: postoperative complete wound coverage with granulation tissue 2 weeks after the application of Hyalomatrix® on the diploic bone after tumor resection; Below center right- intraoperative view after partial-thickness skin grafting 3 weeks after tumor resection; Below extreme right: postoperative aspect 1.5 years after skin grafting.



Fig. 4: Above left- preoperative view of a 75ys old male, affected by a relapsing infiltrating squamous cell carcinoma of the scalp with suspicious diploic bone infiltration; Above center- intraoperative view showing wide tumor excision with 15 mm of surgical skin margins; Above right- intraoperative view showing the defect after cancer resection with an area of external cortical bone excision and a central area with a full thickness bone excision and dura mater exposure; Below left- intraoperative view showing the elevation of an axial scalp flap base on the right occipital artery; Below center- intraoperative view showing the scalp defect covered with the described flap and the flap donor area with a partial thickness skin graft; Below right- postoperative aspect 1 year after reconstruction.

In case of a full-thickness skull bone defect, reconstruction is not always necessary or recommended. It is sometimes convenient to defer the wound coverage after final histology is obtained with confirmation of margin clearance, reconstructing in conditions of oncological safety ⁶⁻⁹.

Secondly, reconstruction must be a process of restoring form and function.

Size and location of the bone defect and expected intracranial pressure are important determinants for considering bone reconstruction in the acute stage. Larger

bone defects can result in a spectrum of complaints ranging from headaches and motion intolerance to seizures and aesthetic concerns. There are no firm rules on defect diameters and bone replacement requirements. Defects with a diameter of 5 to 7 cm are considered as medium. Morcellized bone can be used for small skull defects and calvarial bone or rib grafts are suitable for medium sized defects. The harvest of calvarial bone grafts is not favoured in these generally older oncology patients for oncologic reasons⁹. Patients with a recent history of infection and necrosis and patients who are likely to receive post-operative irradiation are excluded for nonvascularized bone grafts or prosthetic material, such as polymethylmethacrylate, hydroxyapatite cement, or titanium as reconstructive options at the time of ablative surgery. Vascularized ribs for structural support in combination with the latissimus dorsi muscle can be used to cover large defects¹⁰. In the case of dura defects, fibrin glue is only used to close small dura defects. Artificial patches [e.g., Gore-Tex (W.L. Gore&Associates, Flagstaff, Ariz.), NeuroPatch (B. Braun Melsungen AG, Melsungen, Germany)] and nonvascularized fascia grafts are mainly, but not exclusively, used in nonirradiated areas to reduce the risk of infection. Vascularized fascia lata (in a musculocutaneous anterolateral thigh flap) is an option for reconstructing dura defects that have been previously irradiated¹¹.

With the advent of new dermal substitutes, the choice of more demanding reconstructive procedures (i.e. pedicle or free flaps) becomes less compelling and the possibility to cover the exposed bone with a dermal matrix makes the reconstructive procedure easier and less cumbersome for the patient, reducing the costs of care and hospitalization. These biomaterials are opening up to easier and less stressful possibilities of reconstruction for the patient (less lengthy interventions, lack of morbidity of the donor areas, faster postoperative rehabilitation). Currently, many authors have contributed their expertise on the possibility of using dermal matrix on loss of substance with bone exposure¹⁰⁻¹⁵.

Some authors have integrated the use of negative pressure therapy with the use of the dermal matrix to increase the local blood supply^{13, 16-18}.

Generally, the wounds that do not contain a sufficient blood flow to the survival of graft, with exposed bone or tendon, require the use of flaps. Especially at the calvarium, the amount of dermis influences the durability, functional, and aesthetic properties of the skin graft. If wound does not result in a well-vascularized granulation bed then local, distant or free flap coverage may be necessary, because the skin graft has a certain degree of failure of skin take, depending entirely on the re- and neo-vascularization coming from the wound bed^{19,20}. Even today, for most patients, flaps remain the ideal treatment, but some of them are not candidates for more demanding reconstructive surgery; moreover, often these procedures are associated with long hospitalizations, risk of infection, thrombosis, and loss of flaps²¹.

Surgical strategies vary with the cause and size of the defect, the quality of the surrounding local tissue, considering patient's health condition, age and will. The following are the basic methods used to cover exposed bone.

OUTER TABLE REMOVAL WITH DIRECT OR DELAYED GRAFTING

Immediate skin grafting after removal of the outer table results in a bumpy coverage that is prone to ulceration. Delayed grafting after granulation of the wound created by removal of the outer table is reported to yield a stable graft with minimal chance of skin graft breakdown¹².

LOCAL SCALP FLAP(S) WITH GALEAL SCORING

Small Defects (<6 cm)

The use of local flaps is generally the best method to close these wounds. The flaps are raised above the pericranium and are based on the major nutrient blood supply. The nonstretchable scalp can be made to cover a larger area by scoring the galea perpendicular to the direction of tension. Great care must be taken to avoid injuring the vessels in the supragaleal plane¹³. If the flap must be widened, the galea can be cross-hatched to relieve tension. Almost all flaps require galeal scoring to provide successful closure. If the scalp loss is in a conspicuous area (i.e., hairline), it is wise to transpose a hair-bearing flap from a location that can be more easily camouflaged. In small defects the donor area can be closed primarily or, if necessary, covered with a split-thickness skin graft. These flaps should be designed to take advantage of neck skin laxity. Mobilization of scalp adjacent to the donor defect, with galeal scoring, may aid in donor site reduction.

Medium-Sized Defects

When dealing with these larger defects, the principles of closure remain the same. The best choice is usually a large-scalp flap with skin grafting of the donor pericranium.

In some cases, use of multiple axial flaps is helpful. This concept was initially described as a four-flap technique, utilizing the entire remaining scalp to close the defect⁴⁻¹⁰. This technique was then modified to a three-flap technique in which two smaller flaps adjacent to the defect are used to provide primary wound closure and a third larger flap, consisting of the entire remaining scalp, is used to close the donor defect following rotation of the two smaller flaps. These flaps are based on known vascular territories and can be used to cover defects up to one-third of the scalp surface area.

The width of the two smaller flaps should be at least one-half the width of the primary defect so that, when mobilized and juxtaposed, they automatically cover the raw surface. The larger flap includes the rest of the scalp. If the defect is lateral to the midline, the base of the pedicle of the large scalp flap should be based on the contralateral side of the defect. These flaps are elevated in the loose areolar plane, and will require extensive undermining of the remaining scalp, forehead, and nape of the neck. Care must be taken when performing lateral dissection so as to avoid injury to the vascular pedicles as they enter the scalp.

Large Defects (8-10 cm)

When the defect is large, anterior, and off to one side, a subtotal scalp flap can be raised (Fig. 4). Based on the superficial temporal and posterior auricular arteries, the remaining scalp can be transposed with a large donor deficit that must be grafted. The back-cut in the occipital region may require special attention (e.g., padding), as it may break down if the patient lies on it. Better results are obtained with a free flap.

Pericranial Flaps and Overlying Skin Grafts or Local Flaps

Pericranial flaps are endowed with a rich vascular network that allows them to be used as pedicled flaps (Fig 5) to cover denuded bone and act as a bed for skin grafting.

Pericranial flaps should be designed larger than the recipient site because of their elastic properties. In addition, the random anastomoses that vascularize these flaps are weakest between major vascular territories. Thus, they must be based on major vascular territories that do not cross the midline. The advantages of the pericranial flaps are their minimal donor site morbidity and dependabil-

ity as a bed for skin grafting. However, these flaps should be laid down in a manner that reduces pressure (i.e., bolster dressings). The maximum defect size that can be covered by this flap is 7 cm x 12 cm^{xv}.

Tissue Expansion Followed by Local Flap Closure

This technique is an acceptable method of closure without visible change in hair thickness.

Temporary coverage of exposed bone must be obtained before expansion.

Approximately 50 percent of scalp can be reconstructed with expanded scalp tissue.^{xvi} It does require staged operations with a lengthy interval period and is potentially associated with expander complications¹⁷. Stable scalp coverage must be obtained during the expansion process to prevent calvarial desiccation and subsequent osteomyelitis. If the periosteum is intact, it can be primarily skin grafted. When using tissue expansion, the largest expander possible should be placed in a subgaleal position. The shape of tissue expander bases affects the amount of tissue gain. The appropriately sized and shaped expander should be selected on the basis of the individual patient's defect¹⁸. A single large expander is preferred over multiple smaller expanders, as this will give the greatest gain in tissue per volume of expansion and minimize the infectious risk by limiting the number of operative sites. However, in scalp reconstruction, multiple expanders are frequently used in a single setting to gain the greatest amount of expansion per operative procedure. The incision should be small and placed at a distance from the defect, the pocket, and the future flap. Intraoperative filling of the expander reduces the need for drains by preventing hematoma and seroma formation. A good estimation of flap length is twice the height of the expander above the skin surface. Overexpansion by 30% to 50 % makes the procedure more reliable.



Fig. 5: Extreme left: Preoperative view of a 78ys old male, affected by radiodermatitis with bone exposure after radiotherapy for cerebral neoplasm; Center left: Preoperative markings for extended trapezium flap reconstruction before surgical delay; Center right: Postoperative view of pedicled trapezium flap after 4 week; Extreme right: Postoperative view of final reconstruction after section of pedicle.

External tissue expanders may be an alternative to internal expansion in selected cases. They provide constant tension across a wound to accomplish wound closure through less invasive methods. There are many available external tissue expanders utilizing hooks, sutures, metal footplates or elastomer-based adhesive strips for adherence to the skin¹⁹⁻²¹.

Microvascular Flap Coverage

When local flaps are not an option, management of large scalp frequently requires free flap coverage. Free tissue transfer is the only available option for full-thickness defects of the entire scalp. Several free flap options are available for scalp and forehead reconstruction. These choices depend on different factors such as patient characteristics, defect variables, and surgeon preference²²⁻²⁶. Free tissue transfer allows for successful reconstruction in high-risk patients in whom local reconstructive techniques would likely fail. Although many of these patients will eventually die as a result of their disease, reconstruction can provide a good quality of life²⁷.

McClellan and Bunke²⁸ described the free vascularized omental transfer for scalp coverage. The omentum was molded to the scalp defect and then covered with a split-thickness skin graft. The necessity of laparotomy and the availability of less morbid flaps have limited the usefulness of this transfer. The latissimus dorsi muscle, which can be transferred as a myocutaneous unit or as a free muscle only and covered with a split-thickness skin graft, was first used in 1978 to cover a scalp defect²⁹. The muscle is large enough to cover the entire scalp and is reliable in its anatomy. In addition, the thoracodorsal artery and vein provide a long pedicle that aids in the utility of this flap.

The parascapular flap is more bulky than the latissimus dorsi flap but does not sacrifice a functional muscle. It cannot cover the entire scalp. These flaps are unsatisfactory from an aesthetic standpoint and do not restore hair-bearing tissue to the scalp.

An alternative option in scalp reconstruction is the use of the anterolateral thigh flap. This flap offers structural and cosmetic advantages for most scalp defects³⁰.

The fascial layer of the fasciocutaneous anterolateral thigh flap can easily be used as a source of vascularized fascia to replace defects of the dura mater³¹. The well-vascularized fascia component will be useful in the management of wound healing of the dura and will prevent leakage of cerebrospinal fluid and infection of the underlying cerebral tissues. Also, total scalp reconstruction is possible with bilateral anterolateral thigh flaps³².

The aesthetic result is an important factor affecting quality-of-life outcome of microsurgical reconstruction of the scalp and forehead. Disadvantages in aesthetic outcome such as skin colour or texture mismatch and excess bulk of the flap are readily noticeable.

Bioresorbable dermal substitute

Patients affected by infiltrating large tumors of the scalp and American Association of Anesthesiologists (ASA) class III may be not candidate for any of the above described aggressive surgical procedures.

In this category of patients, during the same surgical procedure, the defect can be covered by applying dermal substitutes on the pericranium, the diploic bone or dura (Fig. 3)³³⁻³⁹.

The dermal regeneration template for excellence is Integra® (Integra Lifesciences, Plainsboro, NJ), a derivative of organic synthesis; it consists of bovine collagen polymerized with copolymers of GAG (glycosaminoglycan). It is the most widely used dermal substitute.

This dermal regeneration template allows obtaining an appropriate coverage and an optimal aesthetic outcome. In the absence of autologous dermis, staged reconstruction with a dermal equivalent or dermal regeneration template may offer a good reconstructive option in selected cases⁴⁰⁻⁴⁴.

Advantages in using these templates are the ease of use and the ability to induct neodermis formation to obtain optimal graft take after wide oncological demolitions. Firstly, this conduct can assure surgical radicality reducing the possibility of relapse, even in the most aggressive and infiltrating tumors. Secondly, reconstruction can restore form and function. Good bone coverage with recovery of a sufficient soft tissue thickness and a good morphology can be achieved. Moreover, patients requiring oncologic surgery of the scalp are often elderly, with comorbid illness, so that a complex reconstruction is not always recommended, and sometimes surgery has to be abandoned in favor of radiotherapy⁴⁵.

The use of this dermal templates is a valid technical option that gives a good result, is accepted by patients, and is easy to be applied. Dermal substitutes have enormous potential to allow an increase in therapeutic options available to the surgeon and the patient's benefit. However, especially in case of elderly patients with poor performance status and large wounds, new options for wound bed preconditioning, like artificial dermis or topical negative pressure therapy, have to be taken into consideration⁴⁶. Tissue engineering combines advances in cell culture technology to medical and surgical advances in science to allow for new solutions though synthetic substitutes increasingly effective and efficient

Discussion

The loss of skin envelope has been one of the oldest, yet most frequent and costly problems in our health care system. To restore functional and aesthetic integrity of scalp in patients for oncological reasons, an armamentarium of reconstructive surgical procedures including autogenous, allogeneous and xenogeneous tissue transfer as

well as implantation of alloplastic materials. The proper choice of a reconstructive technique is affected by several factors: the size and location of the defect, the presence or absence of periosteum, the quality of surrounding scalp tissue, the presence or absence of hair, location of the hairline, and patient comorbidities. The best replacement for scalp tissue is scalp tissue. There is no other donor site in the body that will approximate the same hair-bearing qualities of scalp tissue. Rotation-advancement flaps using scalp mobility from the parietal regions are the workhorse of reconstructive techniques. Proper design of these flaps requires preservation of the native hairline, redirection of hair follicles in acceptable patterns, incorporation of major vascular pedicles, and closure without excessive tension, which can be accomplished with galeotomies or use of stress relaxation and creep. In many instances, local tissues are inadequate for defect reconstruction. This may occur if the defect is prohibitively large, if local tissues are traumatized, or if rotation-advancement flaps would require disruption of normal hair patterns and hairlines. When this occurs, as long as hair-bearing scalp remains, tissue expansion is the reconstructive technique of choice. If inadequate scalp is present to allow for tissue expansion, free tissue transfer offers the best reconstructive option.

Conclusion

Successful reconstruction of these defects requires a detailed knowledge of scalp anatomy, careful preoperative planning, hair physiology, skin biomechanics, variety of possible local tissue rearrangements and plastic surgery procedures as well as synthetic substitutes or products provided by tissue engineering. However, the challenge today is to do so with excellent cosmetic results.

Riassunto

La ricostruzione dello scalpo è sempre stato un compito arduo ed una sfida, in particolare dopo una demolizione oncologica, e questo articolo offre una visione globale dello stato dell'arte sulle strategie ricostruttive. A questo scopo abbiamo elaborato un algoritmo sistematico per la ricostruzione dello scalpo basato sulla sede e l'estensione del difetto, la presenza o meno del periostio, il coinvolgimento osseo, la qualità dello scalpo circostante, la presenza o meno dei capelli, la localizzazione della linea del capillifero, le comorbidità del paziente e le differenti procedure comunemente usate in chirurgia plastica.

Come risultato il nostro algoritmo consente ai chirurghi plastici di procedere alla ricostruzione dello scalpo dopo i difetti più devastanti, ed il successo della ricostruzione richiede una attenta pianificazione preoperatoria ed un

approfondita conoscenza dell'anatomia dello scalpo, la fisiologia dei capelli, la varietà dei tessuti localmente disponibili e le procedure di chirurgia plastica, come pure la conoscenza dei sostituiti sintetici e dei prodotti forniti dall'ingegneria tissutale.

La sfida attuale è comunque quella di ottenere risultati cosmetici di eccellenza, di cui sono esempio i cinque casi dell'iconografia.

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