Original article

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Primary reconstruction of skull vault defects after burns

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Restoration of skull vault defects is especially important in the early stages of treatment, which minimizes the number of purulent and necrotic complications involving both the skull and the underlying deep structures.

Objective: To develop the most rational approach and surgical tactics for the rehabilitation treatment of patients with defects of the cranial vault after burns under conditions of primary reconstruction.

Materials and methods: We observed 16 patients with cranial vault lesions aged from 2 months to 46 years (average age, 25.3 years). Three groups of patients were identified.

- Lesions of superficial tissues without periosteal involvement (4 patients 25.0%);

- Soft tissue and periosteum lesions with exposure of the cortical bone layer (6 patients, 37.5%).

- Deep soft tissue and bone lesions (6 patients, 37.5%)

Depending of the depth, area of damaged tissue and localization of the defect, as well as the presence of unaffected areas, skin grafting, revascularizing interventions using complex flaps, bone milling or removal were used.

Results: The engraftment of skin grafts in patients in whom this method was used as the primary technique for closing defects was 70%. Complete engraftment of local and regional flaps occurred in all cases. Necrosis of up to 30% of the trapezius muscle flap occurred in one case. The study demonstrated the possibility of primary closure of cranial vault defects in patients with various lesions of anatomical structures.

Conclusions: The use of a differentiated approach to the treatment of skull vault defects ensures favorable therapeutic outcomes for patients.

Keywords: *cranial vault defects; post-burn cranial injury; complex flaps; plastic surgery; primary reconstruction; cranial defect closure*

Introduction

Defects of the cranial vault develop following deep flame burns, electrical and thermomechanical injuries, mechanical trauma, and infectious lesions of the soft tissues. Surgical treatment of this category of patients represents a complex clinical challenge because of the deficiency of soft tissues. This necessitates a nonstandardized approach to the selection of treatment strategies and surgical techniques [1].

Surgical management of these patients requires meticulous preoperative planning, which significantly reduces the risk of postoperative complications and improves the long-term quality of life of affected individuals [2].

Tissues of the cranial vault from adjacent areas are commonly used for defect reconstruction. However, the frequent damage to surrounding tissues and the presence of degenerative and dystrophic changes often necessitate revascularization of the affected area [1]. Fasciocutaneous and musculocutaneous flaps are best suited to these requirements, providing well-vascularized tissue coverage and stable skin reconstruction [3–6]. Nevertheless, the high incidence of complications, as well as the complexity and prolonged duration of microsurgical procedures, limit their widespread use. Damage to the aponeurotic layer, periosteum, and cranial bones requires the development of new reconstructive approaches.

Restoration of cranial vault defects is particularly important in the early stages of treatment, as it minimizes the risk of purulent and necrotic complications involving both the skull and the underlying deep structures.

Objective. To develop the most rational approach and surgical tactics for the rehabilitative treatment of patients with cranial vault defects after burns under conditions of primary reconstruction.

Materials and methods

Study participants

The study included 16 patients with cranial vault injuries aged from 2 months to 46 years (mean age, 25.3 years), five of whom were children under 14 years. Among the patients, 11 were male and 5 were female.

In 9 (56.2%) patients, the defects developed as a result of flame burns; in 4 (25.0%), after high-voltage electrical injuries; in 1 (6.2%), after a scald burn; in 1 (6.2%), after a chemical burn caused by sulfuric acid; and in 1 (6.2%), as a result of a contact burn. The total body surface area affected ranged from 1% to 60% (mean, 21.3%). The defect area ranged from 60 to 280 cm² (mean, 170.5 cm²).

Inclusion criteria:

- male and female patients aged from 2 months to 50 years;
- patients with cranial vault defects after burns;
- obtained informed consent for data collection, processing, and publication of aggregated results while maintaining strict confidentiality.

Exclusion criteria

- age over 50 years;
- cardiovascular, pulmonary, or cerebral dysfunction, as well as other diseases in the stage of subcompensation or decompensation;
- tuberculosis;
- HIV infection;
- positive Wassermann reaction (RW) test result;
- psychiatric disorders;
- refusal to participate in the study.

Group characteristics

When selecting the surgical strategy and treatment methods, the depth and extent of tissue damage, defect localization, and the presence of unaffected adjacent tissues were taken into account. Accordingly, three groups of patients were identified:

- lesions of the covering tissues extending to the periosteum of the cranial bones (4 patients, 25.0%);
- lesions of the soft tissues and periosteum with exposure of the cortical bone layer (6 patients, 37.5%);
- deep lesions involving both soft tissues and cranial bones (6 patients, 37.5%).

Surgical treatment was generally performed 2–4 days after hospital admission. During the preoperative period, intensive infusion and transfusion therapy was administered, including blood products when indicated, agents aimed at improving hemomicrocirculation, and antibiotics. Locally, wet-to-dry dressings or hydrophilic ointments were applied. In 8 (50.0%) patients, preoperative preparation lasted more than 6 days because of the need to correct cardiovascular function and carbohydrate metabolism parameters.

Study design

A retrospective, single-center, cross-sectional interventional clinical study was conducted.

The treatment outcomes of patients with cranial vault defects who underwent treatment at the Department of Reconstructive and Restorative Surgery of the Municipal Non-Commercial Enterprise Kyiv City Clinical Hospital No. 2 (renamed in March 2025 as the "Kyiv City Medical Center," Clinical Unit No. 8) between 2019 and 2024 were analyzed.

Written informed consent for participation in the study and publication of the data was obtained from all patients or their relatives. The study protocol was approved by the Ethics and Academic Integrity Committee of the Shupyk National Healthcare University of Ukraine (Minutes No. 4/38 dated April 30, 2024).

Statistical analysis

Descriptive statistical methods were used to process the obtained data. The results are presented as absolute and relative values. Descriptive statistics were applied to summarize the studied parameters.

Results

In the early postoperative period, treatment outcomes were assessed according to the following criteria: flap engraftment, occurrence of necrosis, and purulent complications.

The engraftment rate of free skin autografts in patients for whom this method served as the primary technique for defect closure was 70%. Incomplete graft engraftment was observed during reconstruction of granulating wounds in cases of superficial lesions. Better engraftment was achieved in the reconstruction of donor sites after the formation of local or regional flaps, as well as on granulation tissue formed following tissue ingrowth through a polypropylene mesh. After wound bed preparation, the exposed areas were re-covered with free skin grafts.

Complete engraftment of local and regional flaps was observed in all cases. Necrosis involving up to 30% of a vertical musculocutaneous flap was recorded in one case. After debridement of the necrotic tissue, the defect was closed using a temporal flap based on the occipital branch of the superficial temporal artery. Flap viability monitoring was performed only during the inpatient treatment period.

Suppuration associated with the use of a free flap was observed in one case.

The methods used for reconstruction of cranial vault defects are presented in ***Table 1***.

Discussion

The key criteria for selecting a method for primary reconstruction of calvarial defects following burns include the size and depth of the defect, preservation of the skin and deeper structures, as well as the presence and length of the soft-tissue vascular pedicle [7].

For reconstruction of scalp soft-tissue defects, local flaps advanced by direct advancement, rotation, or transposition, latissimus dorsi muscle flaps, omental flaps, and free flaps are used [8].

Scalp reconstruction differs depending on the anatomical region in which the defect is located and on its size. In our series, a single reconstructive technique was rarely used in isolation. In most cases, a combination of different plastic reconstructive methods was applied. For extensive defects, split-thickness skin grafting was used most frequently both for closure of the primary defect and for coverage of the donor site (***Figs. 1–3***). This approach enabled wound closure within a shorter period and with fewer complications [9].

Patients with periosteal involvement required revascularization procedures to preserve the cranial vault bones. Closure of intact bone or deep defects after necrotic tissue removal down to the inner cortical plate was performed using cutaneous-aponeurotic flaps from adjacent regions or complex composite flaps with axial blood supply (***Fig. 4***). In cases involving the periosteum or cortical layer of the cranial bones, bone milling was performed to improve flap fixation. This procedure also

Table 1. Clinical characteristics of patients and methods of primary reconstruction of cranial vault defects after burns

Depth of lesion	Age, years	Sex	Etiological agent	Total burn area, %	Defect area, cm^2	Defect localization	Primary reconstruction methods	Additional methods
Up to the periosteum, n=4	5	F	Scald burn	8	80	Parietal, temporal regions	ASG	–
	22	M	Flame burn	20	180	Frontal, parietal regions	ASG	–
	35	M	Flame burn	15	200	Parietal, temporal regions	ASG	–
	26	F	Chemical burn	12	130	Frontal region	ASG	–
Including the periosteum, n=6	12	M	HVEB	40	130, 80	Parietal, temporal regions	Bone milling + rotational flap + HTMF + ASG	–
	43	M	Flame burn	25	140	Occipital region	VTMF	ASG
	45	M	Flame burn	15	220	Parietal, temporal regions	Bone milling + rotational flap + ASG	–
	38	F	Flame burn	18	200	Parietal, frontal regions	Bone milling + ASG	–
	9	F	Flame burn	15	220	Parietal, occipital, temporal regions	VTMF + HTMF + temporal flap + ASG	ASG
	36	M	Flame burn	18	180	Frontal region	Two temporal flaps	ASG
Bone (cortical layer), n=4	26	M	Flame burn	45	280	Parietal, occipital regions	Bone milling + free flap + ASG	–
	46	M	HVEB	14	150	Parietal, temporal regions	Rotational flap + ASG	
	22	M	HVEB	15	180	Parietal region	Rotational flap + ASG	–
	26	M	Contact burn	1	60	Occipital region	Rotational flap + ASG	–
Bone (full thickness), n=2	2 monts	F	Flame burn	18	140	Parietal region	Bone removal + mesh implantation + ASG	–
	14	M	HVEB	60	180	Parietal, occipital regions	Bone removal + mesh implantation + rotational flap + ASG	–

Notes. HVEB — high-voltage electrical burn; ASG — autologous skin grafting (autodermoplasty); VTMF — vertical trapezius muscle flap; HTMF — horizontal trapezius muscle flap.

promoted ingrowth of granulation tissue through the burr holes. The cortical layer subsequently became covered with granulation tissue, allowing defect closure with free grafts and thereby accelerating recovery (see ***Figs. 2 and 3***).

Temporal flaps based on the superficial temporal artery were used as revascularizing flaps. To increase the area of coverage, a double flap supplied by the parietal and occipital branches of the superficial temporal artery was created (***Fig. 5***).

The temporal region represents a favorable donor site due to its rich vascular network and the availability of different tissue types, including skin, fascia, muscle, and bone [10]. Consequently, multiple flap variants can be designed in this region using one or more tissue components based on the superficial temporal artery and its branches, depending on the location and origin of the defect [11, 12]. In our study, temporal flaps were used for reconstruction of parietal defects. In cases involving the frontal region, a temporal fascial flap was used to cover the affected bone, followed by free skin grafting (see ***Fig. 5***).

The trapezius muscle flap is considered the first-choice option for some patients with defects in the posterior regions of the cranial vault because of its proximity to the wound, reliable blood supply, and increased resistance of flap tissues to infection [4,13]. The location and orientation of the dominant vascular pedicles of the trapezius muscle allow the formation of two flap variants: a horizontal flap including the horizontal portion of the muscle based on the descending superficial branch of the transverse cervical artery, and a vertical flap including the vertical portion of the muscle based on the deep nourishing branch of the transverse cervical artery [5].

The use of regional musculocutaneous flaps based on the trapezius muscle offers the advantage of providing an adequate volume of well-vascularized reconstructive tissue, while transfer of tissue on a vascular-muscular pedicle substantially reduces the risk of thrombosis of the supplying vessel [13, 14].

In selected cases, the horizontal and vertical trapezius musculocutaneous flaps may be considered the only reconstructive option capable of achieving closure of occipital and temporal defects and enabling delayed corrective procedures [13, 14] (***Fig. 6***).

During flap formation, in one case of vertical flap dissection, the cutaneous component extended 5 cm caudally beyond the inferior border of the trapezius muscle, which subsequently resulted in impaired blood circulation within the skin fragment and partial necrosis. In the horizontal flap, the muscular component was located only in the superomedial portion, whereas the remaining part contained fascia alone.

The horizontal trapezius musculocutaneous flap is indicated for reconstruction of temporoparietal defects, whereas the vertical trapezius musculocutaneous flap is preferable for closure of occipitoparietal defects.

Pedicle correction is required after 4–6 months to achieve a satisfactory cosmetic outcome.

An important aspect of primary calvarial reconstruction is the closure of bone defects in cases of total bone necrosis, including selection of an appropriate method for protection of the intracranial contents and prevention of cerebral prolapse [15].

For closure of cranial vault defects with exposure of the dura mater or brain structures, polysynthetic materials such as protacryl, biocomposite materials, corundum implants, carbon-based materials, as well as bone grafts, are used [16, 17]. The disadvantages of these methods include the inability to use plates during the acute phase of injury, limited applicability for extensive bone defects, absence or deficiency of adequate skin coverage for soft-tissue reconstruction, and restricted use in pediatric patients.

Fig. 1. Female, 28 years old: (A) second-degree superficial partial-thickness and third-degree chemical burn caused by sulfuric acid involving the frontal and temporal regions of the scalp without injury to the periosteum, as well as the upper extremities (12% TBSA); (B) wound appearance after staged debridements; (C) wound closure using a thick split-thickness autograft

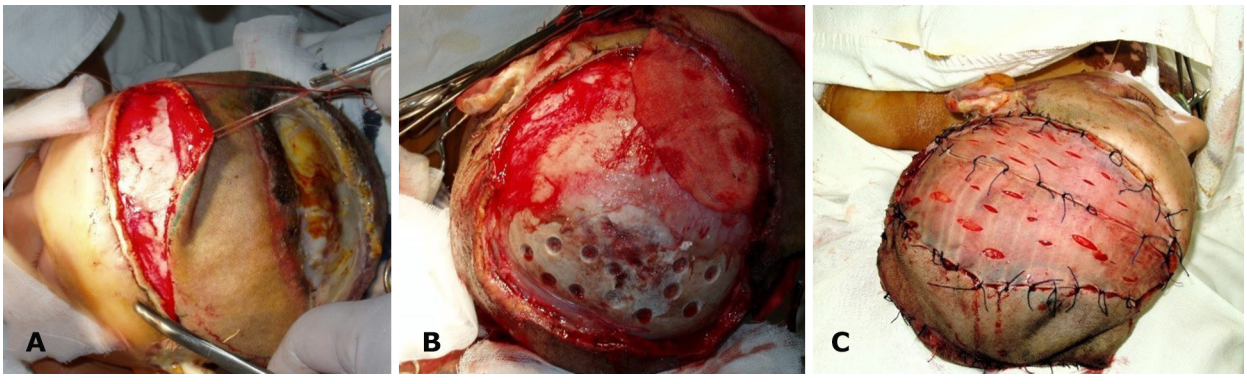

Fig. 2. Boy, 12 years old (case shown in Fig. 6): (A) formation of a parietal cutaneous-aponeurotic flap; (B) burring of the exposed parietal region; (C) reconstruction of the exposed burred parietal bone with a flap. The donor wound was covered with a split-thickness dermatome graft

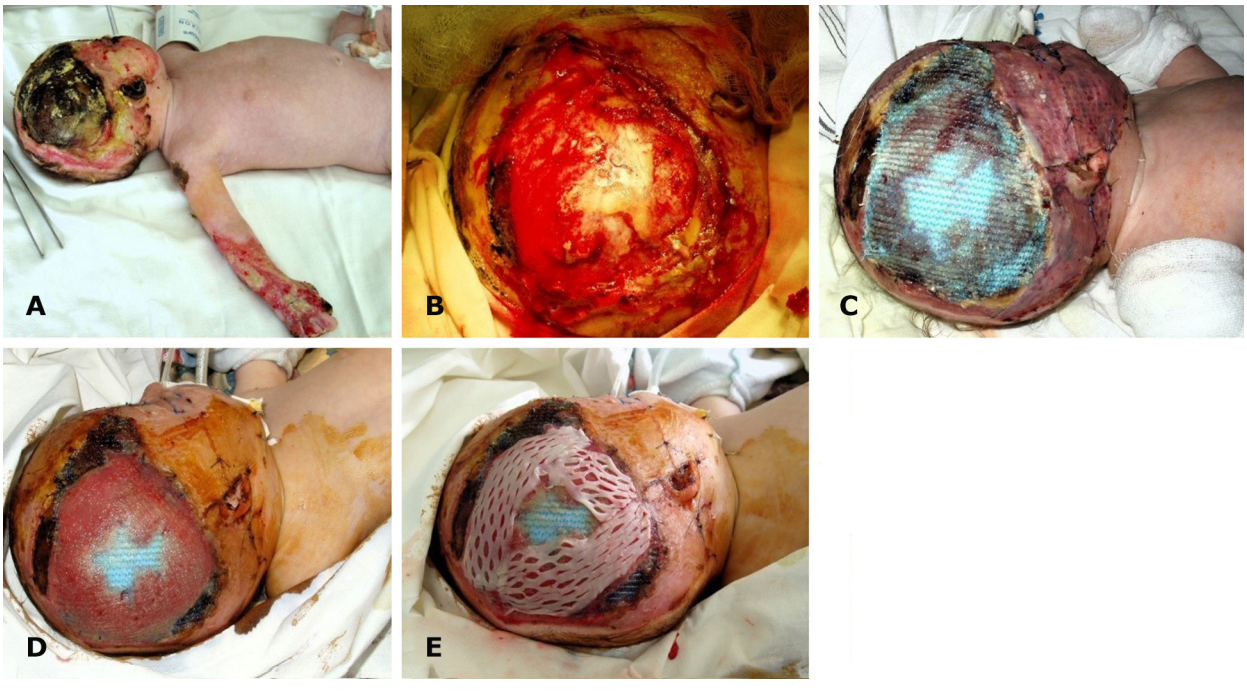

Fig. 3. Female infant, 2 months old. Second-degree superficial partial-thickness and third-degree flame burn of the scalp and right upper extremity (18% TBSA): (A) full-thickness necrosis of the temporal and parietal bones measuring 6 × 8 cm, with surrounding soft-tissue necrosis measuring 10 × 15 cm; (B) resection of the affected areas of the parietal and temporal bones with exposure of the dura mater; (C) polypropylene mesh sutured to the aponeurosis along the margin of the bone defect to protect the intracranial contents; (D) formation of granulating tissue through the mesh openings with development of a stable framework; (E) coverage of the granulation surface with a thick split-thickness dermatome graft

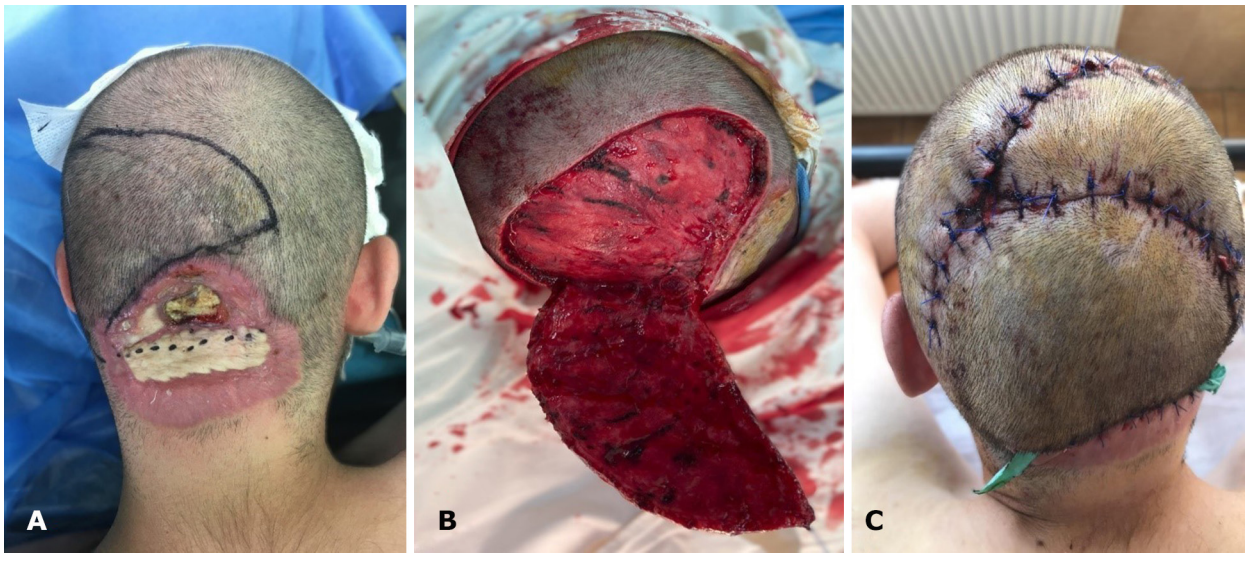

Fig. 4. Male, 24 years old: (A) second-degree deep partial-thickness and third-degree contact burn with a soft-tissue defect in the occipital region involving the periosteum and outer cortical layer of the occipital bone; (B) condition after wound debridement and removal of the damaged cortical plate to the level of punctate bone bleeding; (C) wound closure using a local occipital rotational flap incorporating the occipital artery. An additional parietal flap was used to cover the donor site

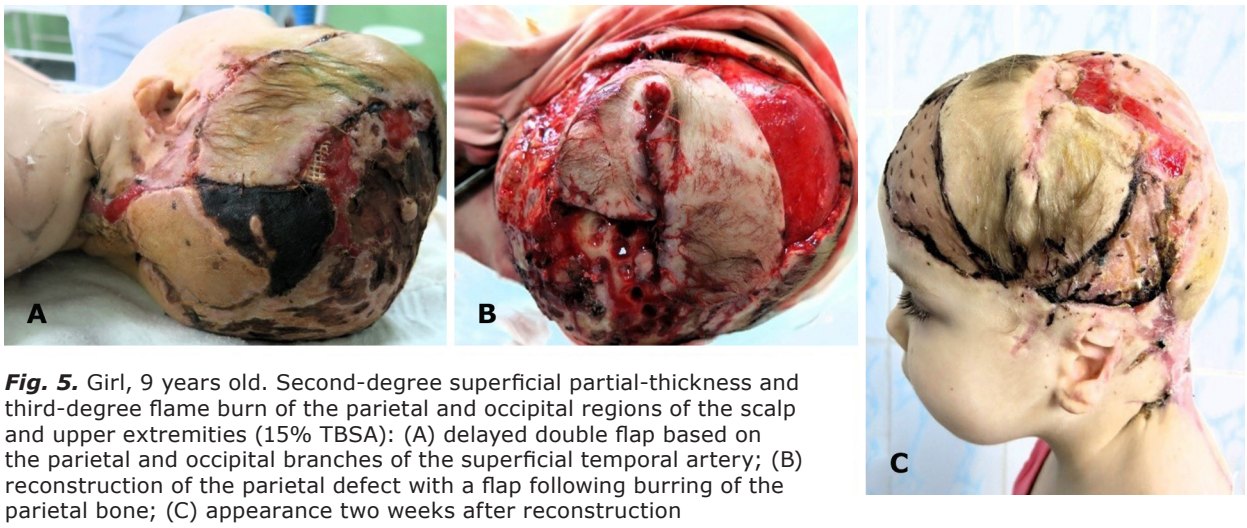

Fig. 5. Girl, 9 years old. Second-degree superficial partial-thickness and third-degree flame burn of the parietal and occipital regions of the scalp and upper extremities (15% TBSA): (A) delayed double flap based on the parietal and occipital branches of the superficial temporal artery; (B) reconstruction of the parietal defect with a flap following burring of the parietal bone; (C) appearance two weeks after reconstruction

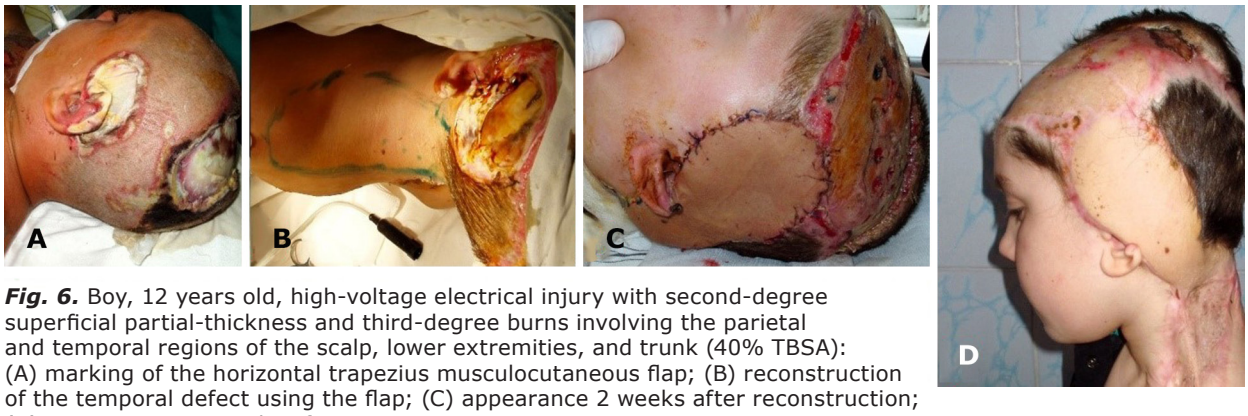

Fig. 6. Boy, 12 years old, high-voltage electrical injury with second-degree superficial partial-thickness and third-degree burns involving the parietal and temporal regions of the scalp, lower extremities, and trunk (40% TBSA): (A) marking of the horizontal trapezius musculocutaneous flap; (B) reconstruction of the temporal defect using the flap; (C) appearance 2 weeks after reconstruction; (D) appearance 3 months after reconstruction

To reduce the number of complications associated with closure of cranial vault bone defects, we used polypropylene mesh, which allowed granulation tissue to grow through the mesh openings and ensured coverage of the superior mesh surface with granulation tissue. Such wounds were subsequently covered with free grafts (see ***Fig. 3***).

Conclusions

Injuries limited to the soft tissues of the cranial vault with preservation of periosteal viability allow defect closure by autologous skin grafting. In cases involving tissue damage extending deeper than the periosteum, revascularization procedures using complex flaps, bone burring, or bone resection are required.

The use of a differentiated approach in the treatment of cranial vault defects made it possible to achieve positive outcomes in 14 (87.5%) patients.

Disclosure

Conflict of interest

The authors declare no conflict of interest.

Ethical approval

All procedures performed in studies involving human participants were conducted in accordance with the ethical standards of the institutional and national research committee and with the 1964 Declaration of Helsinki and its subsequent amendments or comparable ethical standards.

Informed consent

Written informed consent was obtained from each patient or their legal guardian prior to surgery.

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