



THE BENEFITS OF EARLY SURGICAL TREATMENT OF DEEP CERVICAL BURNS IN CHILDREN

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Background. The frequency of deep cervical burns in children is four times higher than that of deep face burns. Currently, there is no consensus on the methods for surgical treatment of deep burns in cervical areas; meshed skin autografts continue to be used.

Aim. To evaluate the benefits of early surgical treatment of deep cervical burns in children between the third and fifth days from the moment of injury.

Materials and methods. Case-control study. Surgical treatment was performed in 81 children with deep cervical burns. The main group with early surgical treatment included 46 children and underwent surgical treatment at 3.37 ± 0.14 days from the moment of injury; the control group received autograft during stage treatment for 35 children at 27.17 ± 0.18 days. The treatment results were evaluated by the following indicators: the number of dressing changes, the period of skin restoration, and the area of graft success. In the long term, functional and cosmetic treatment results were evaluated.

Results. In the study and control groups, 7.93 ± 0.45 and 18.75 ± 0.61 dressings were required to complete the treatment, respectively ($p < 0.001$). The skin restoration periods were 16.54 ± 0.68 and 36.94 ± 0.89 days, respectively ($p < 0.001$). The graft success areas were $99.50\% \pm 0.13\%$ in the main group and $93.91\% \pm 2.68\%$ in the control ($p < 0.001$). During the staged surgical treatment, one patient showed a loss of 90% of the graft, which required regrafting. Other complications in the treatment process have not been noted. When assessing long-term cosmetic results using the Vancouver Scar Scale, the average score was 4.0 ± 0.26 points in the main group and 7 ± 0.28 points in the control ($p < 0.001$). The presence of post-burn cicatricial contracture in the main group was noted in 12 (26%) people and the absence in 34 (74%) children. In the control group, 20 (57%) patients required surgical removal of post-burn deformity, and 15 (43%) children did not need further surgical interventions.

Conclusions. Early surgical treatment of deep cervical burns in children on the third and fifth days from injury allows not only to accelerate the process of restoration of the skin but also to directly affect the cosmetic and functional results in a better way.

Keywords: burns; neck; children; autografting; scars.

ПРЕИМУЩЕСТВА РАННЕГО ХИРУРГИЧЕСКОГО ЛЕЧЕНИЯ ГЛУБОКИХ ОЖОГОВ ШЕИ У ДЕТЕЙ

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Обоснование. Глубокие ожоги шеи у детей встречаются в 4 раза чаще, чем глубокие ожоги лица. В настоящее время отсутствует единое мнение о методах хирургического лечения глубоких ожогов шеи, все еще продолжают использовать перфорированные кожные аутооттрансплантаты.

Цель — оценить преимущества раннего хирургического лечения глубоких ожогов шеи у детей на 3–5-е сутки от момента травмы.

Материалы и методы. Исследование — случай-контроль. Хирургическое лечение проведено 81 ребенку с глубокими ожогами шеи. В основную группу (с ранним хирургическим лечением) были включены 46 детей, которым оперативное лечение выполняли на $3,37 \pm 0,14$ сутки от момента травмы. Контрольную группу составили 35 детей, которым осуществляли этапное лечение и выполняли вторичную аутодермопластику на $27,17 \pm 0,18$ сутки. Результаты лечения оценивали по следующим показателям: количество перевязок, срок восстановления кожных покровов и площадь приживления трансплантата. В отдаленном периоде анализировали функциональные и косметические результаты лечения.

Результаты. В основной группе потребовалось $7,93 \pm 0,45$ перевязки для завершения лечения, в контрольной — $18,75 \pm 0,61$ ($p < 0,001$). Кожные покровы восстанавливались через $16,54 \pm 0,68$ и $36,94 \pm 0,89$ дня в основной и контрольной группах соответственно ($p < 0,001$). Площадь приживления трансплантата в основной группе составила $99,50 \pm 0,13$, в контрольной — $93,91 \pm 2,68$ % ($p < 0,001$). В процессе этапного хирургического лечения у одного пациента отмечен лизис 90 % трансплантата, в связи с чем была выполнена повторная аутодермопластика. Другие осложнения в процессе лечения отсутствовали. При оценке отдаленных косметических результатов по Ванкуверской шкале оценки рубцов средний балл в основной группе составил $4,0 \pm 0,26$, в контрольной — $7,0 \pm 0,28$ ($p < 0,001$). Послеожоговая рубцовая контрактура в основной группе отмечена у 12 (26 %) человек. В контрольной группе хирургическое устранение послеожоговой деформации проведено 20 (57 %) пациентам.

Заключение. Раннее хирургическое лечение глубоких ожогов шеи у детей (на 3–5-е сутки от момента травмы) позволяет не только ускорить процесс восстановления кожных покровов, но и улучшить косметические и функциональные результаты.

Ключевые слова: ожоги; шея; дети; аутодермопластика; рубцы.

The neck, like the face, represents an area that has high aesthetic and functional significance [1]. Neck burns in pediatric patients are common. According to various authors, from 7.3% to 20.5% of all victims with burns to the face and neck need surgical restoration of the skin [2, 3]. Deep neck burns in children are registered four times more often than deep face burns [4]. The outcomes of such an injury are usually cicatricial deformities, which result in facial tissue tension and, in severe cases, in tracheal deformity [5]. Post-burn contractures of the neck have a psychosocial effect on the patients; moreover, they can give an idea of suicide [6]. In adults, such cicatricial deformities are static, but in children, during their growth, their severity may increase [5, 7]. It is known that in case of epithelization of burn wounds, for a period of more than 3 weeks, adverse consequences occur in the form of hypertrophic or keloid scars [8, 9]; therefore, combustiologists resort to early surgical treatment of patients with burns and seek to restore the skin as quickly as possible. However, there is still no consensus on the timing of surgical interventions

in the neck; perforated skin autografts are still used even in case of the lack of shortage of donor resources [9–11]. And only the need for a tracheostomy in patients with deep neck burns is an indication for early surgical treatment in this area [12–14]. Currently, there is limited literature data on the treatment of deep neck burns in pediatric patients.

The work aimed to evaluate the benefits of early surgical treatment for deep neck burns in pediatric patients.

Materials and methods

A case-control study was conducted in patients admitted to the children's burn ward of St. Petersburg Children's City Hospital No. 1 with neck burns subject to surgical treatment from 2003 to 2018. Inclusion criteria were age from 0 to 17 years (inclusive) and the presence of a neck burn requiring surgical treatment. The exclusion criteria were the extremely critical condition of the patient and the presence of a concomitant disease being a contraindication to surgical treatment.

Table 1

Data on gender, age, and depth, and total area of burn wounds in patients in the main and control groups

Indices		Main group, <i>n</i> = 46 (56.8%)	Control group, <i>n</i> = 35 (43.2%)	<i>p</i>
Age, years		3.14 ± 0.52 (10 mon.–13 years)	4.09 ± 0.71 (10 mon.–15 years)	0.285
Gender				
<i>n</i> = 49 (%)	M	25 (51%)	24 (49%)	0.195
<i>n</i> = 32 (%)	F	21 (65.6%)	11 (34.4%)	
Depth (degree)				
<i>n</i> = 61 (%)	IIIa and b	33 (54.1 %)	28 (45.9%)	0.553
<i>n</i> = 20 (%)	IIIb	13 (65%)	7 (35%)	
Total area, %		13.33 ± 2.17 (0.5–65)	10.86 ± 1.14 (1–33)	0.316

Note. *p* — the level of significance of differences in statistical indicators in the main and control groups.

Eighty-one patients met the criteria for inclusion in the study.

Patients were divided into two groups: the main group consisted of pediatric patients who underwent early surgical treatment of deep neck burns (*n* = 46, 57%) and the control group comprised patients who underwent classical staged treatment of burn wounds with subsequent autodermplasty (*n* = 35, 43%) The average age of patients was 3.14 ± 0.52 years in the main group and 4.09 ± 0.71 years in the control group. There were more boys in both groups than girls. The depth of burn wounds was determined by visual assessment of the wound surface and histological examination in the laboratory. A four-degree classification of the depth of burn wounds, according to Vishnevsky, was used. The total area of burn wounds was calculated according to the Lund and Browder chart. It ranged from 0.5% to 65% (an average of 13.33% ± 2.17%) in the main group and from 1% to 33% (an average of 10.86% ± 1.14%) in the control group.

The table 1 presents summary data on the patients. Both groups were identical in age, gender, and depth, and area of burn wounds.

Early surgical treatment was performed, on average, 3.37 ± 0.14 days from the moment of injury. All surgical interventions were performed under endotracheal anesthesia. The patient was lying on his back with his head thrown back for optimal access for the surgeon to the surgical field. A soft roller was placed under the shoulder blades. A necrectomy area was marked with a sterile surgical marker. Then, with an electrodermatome

(Aesculap GA630 and 3Ti, Aesculap Inc. A. B. Braun Group Co, USA), Weck blade (Rica Surgical Products Inc., USA), or electric knife, a burn scab was excised in layers before the appearance of diffuse bleeding from deep layers of the dermis or viable subcutaneous fat. The Weck blade was used for necrectomy in the area of the genial-neck angle, where it is impossible to position the electrodermatome blade because of its size. In all cases, the patient's hip was the donor site for taking the auto skin. A split skin graft of 0.2 mm thick was cut with an electrodermatome with a new blade installed and sutured to the edges of the wound defect in the neck. This graft thickness provided epithelization of donor wounds for 10–14 days, which minimized the cosmetic defect, and later, if necessary, the donor site could be reused.

Thinner autografts with a thickness of 0.1–0.15 mm are recommended for use in combination with artificial skin analogs Integra® (Integra LifeSciences, Plainsboro, USA) or Matriderm® (MedSkin Solutions Dr. Suwelack, Billerberg, Germany) since they have a high degree of retraction. Grafts of more than 0.2 mm thickness were not used to restore the skin of the neck, since in such cases, epithelization of the donor wound lasts more than 14 days, and the risk of scar formation in the donor site increases. In necrectomy, wound defects exceeding 15% of the body surface were covered with Syspur-Derm® artificial wound dressing (Hartmann, Heidenheim, Germany). There were no cases when the wound defect was not covered by anything after necrectomy.

After 8–10 days, the artificial wound cover was removed, and autodermoplasty was performed. For draining the hematomas and wound discharge, single perforations of up to 2 mm long were made in the graft with a sharp-pointed scalpel. Then, the graft was covered with gauze mesh, sterile gauze pads moistened with a warm aqueous solution of furacilin, and a broad-spectrum antibiotic. A bandage was applied. The donor wound was covered with a single-layer sterile gauze pad and Branolid-N® (Hartmann) and bandaged. Strict bed rest for 3 days was prescribed to the child, while a soft roller was placed under the shoulder blades, and the pillow was removed. Such conditions ensured the maximum tension of skin autografts and prevented their retraction. On day 3 after surgical treatment, the dressing was first changed. Bandaging of grafts on the neck was always performed under anesthesia. The grafts were visually evaluated for tightness to the wound surface bottom. In the presence of a hematoma or seroma, the graft was punctured. When

a single-layer gauze mesh was consistent, Gioxyson® ointment (Nizhpharm, Russia) was applied to it. Branolid-N® was removed from the donor wound, and Gioxyson® ointment was also applied.

The next dressing was performed on day 5 or 6 after surgical treatment. The graft was visually assessed for mechanical damage and lysis sites, and the consistency of the sutures was determined. The dressing was performed using the Gioxyson® ointment. At that, a surgical collar was put on to prevent the graft retraction. Later, one or two dressings were required before the sutures were removed. Sutures were removed on days 9–11 after surgical treatment. The donor wound was dressed once in 2–3 days. Dressings were changed with Gioxyson®. When epithelization occurred, a single-layer gauze napkin peeled off from the thigh surface on its own. Figure 1 presents a case of early surgical treatment for a deep neck burn.

With classical staged treatment, the wound in the neck was managed in a closed manner. During the first 7–10 days, dressings with ointments

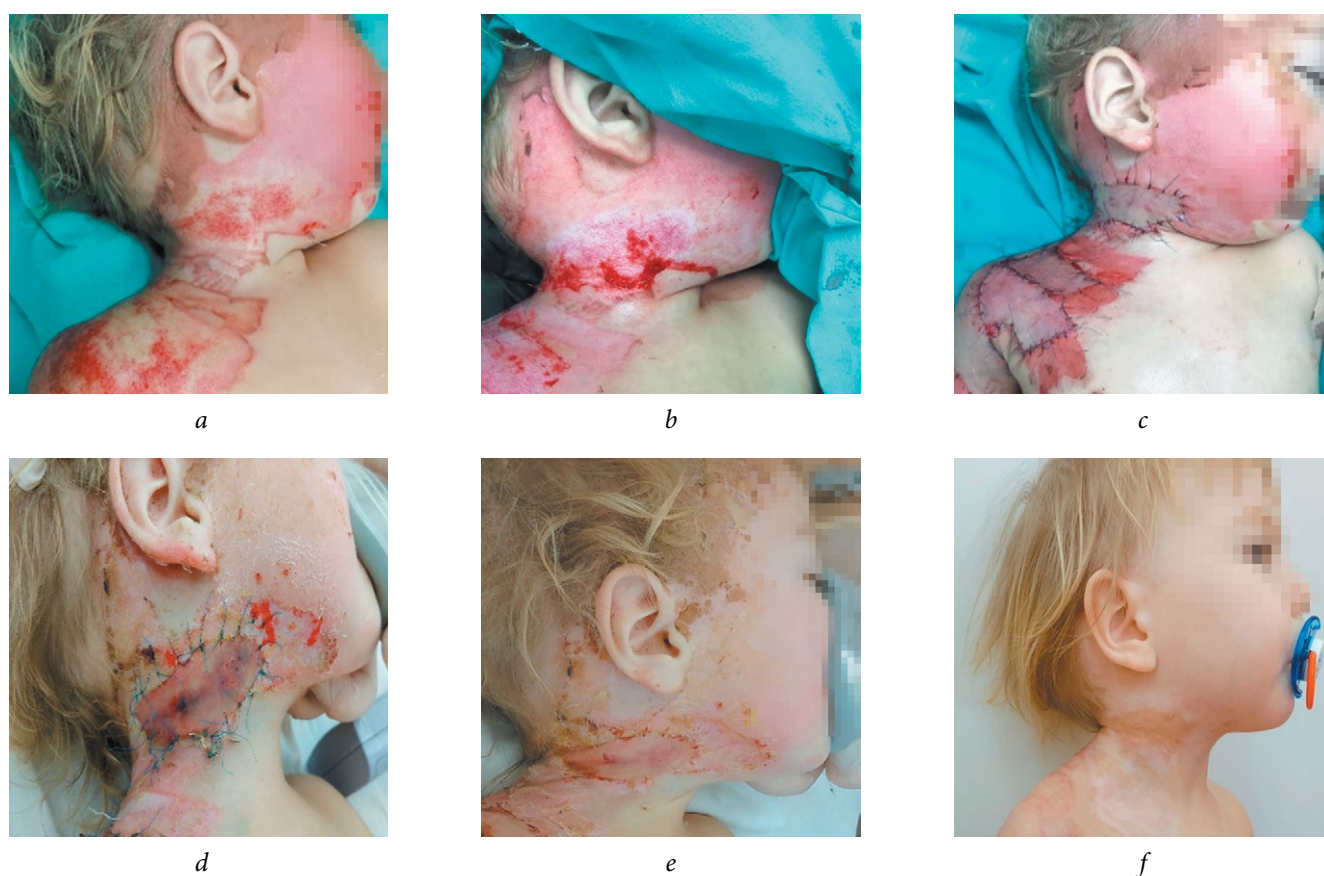


Fig. 1. Pediatric patient K., 1 year 2 months. (a) Diagnosis of thermal burn degrees II–IIIa and b of the face and right side of the neck 3 days after the burn. The wound is represented by a dry motley scab. (b) View of the wound after tangential necrectomy: the wound bed is represented by a deep bleeding layer of the dermis. (c) Burn wound after autodermoplasty: the graft is fixed to the edges of the wound defect with separate nodular sutures with a monofilament thread. (d) Day 3 after early surgical treatment: the graft is pink and tight to the wound. A single small hematoma is determined, which will be emptied. (e) Day 9 after early surgical treatment: the graft retention area is 100%. The sutures have been removed. Restoration of the skin is completed. (f) Month 6 after the early surgical treatment: there is no graft retraction. There is no cicatricial deformity or contracture

Table 2

Term of preparation of the wound for autodermoplasty during the staged treatment with and without a hydrosurgical unit

Staged treatment	Without Versajet® <i>n</i> = 20 (57%)	With Versajet® <i>n</i> = 15 (43%)	<i>p</i>
Autoplasty day (average)	30.15 ± 0.80	23.20 ± 0.83	<0.001

Note. *p* — the level of significance of differences in statistical indicators in the main and control groups.

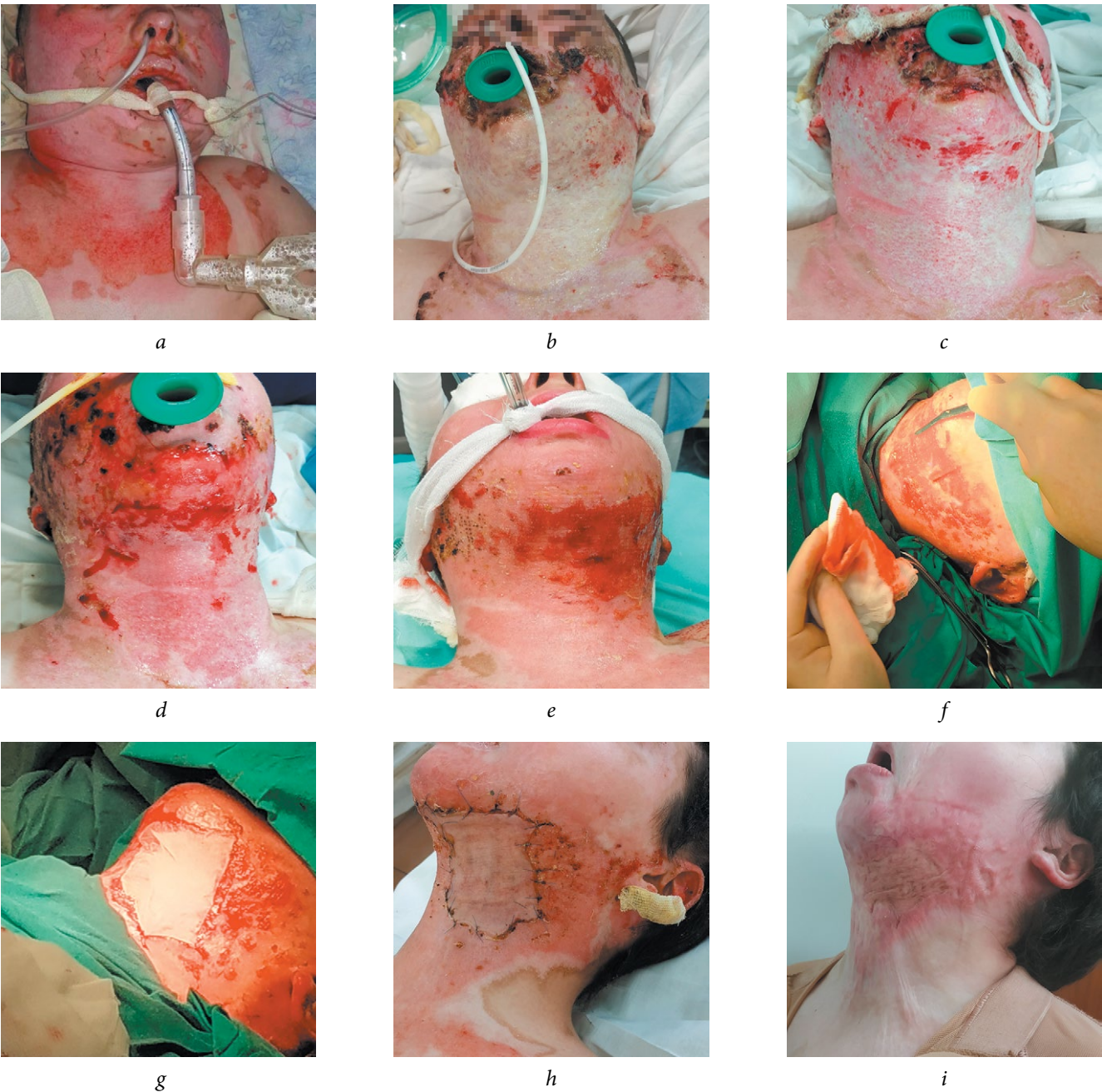


Fig. 2. Pediatric patient D., 15 years old. Diagnosis of thermal burn degrees II–IIIa and b of the face and neck (a) day 2 after the burn. (b) Day 9 after the injury, the appearance of the wound after dressings with silver sulfadiazine. (c) Day 15 after the injury, the wound is actively cleaned of necrotic tissues along with the use of hydrocolloid dressings and debridement with a Debrisoft® sponge. (d) Day 18 after the injury, the wound is completely cleared of necrotic tissue. (e) Day 24 after the injury, the wound is ready for autodermoplasty. (f) Treatment of the granulating wound with a metal debrider. (g) The graft distribution on the wound. (h) Day 9 after autodermoplasty, the graft retention area is 100%. (i) Month 6 after autodermoplasty, the graft retraction, hypertrophic scar growth along the periphery, and the contracture formation were noted

based on silver sulfadiazine were performed once every 2 days. When the eschar softened, its friable areas were removed with a Debrisoft® sponge (Lohmann & Rauscher, Vienna, Austria) or a Norsen metal debrider (Belmed Inc., Bellingham, USA). Suprasorb-H® hydrocolloid dressings (Lohmann & Rauscher) were added to the therapy. In 15 cases, the treatment was performed using a Versajet® hydrosurgical unit (Smith & Nephew, Hull, UK). When using it, the preparation of the wound for autodermoplasty took on average 7 days less (Table 2).

After cleansing the wounds of necrotic tissue, in preparation for autodermoplasty, dressings with Branolind-N® and Levomekol® ointment (Nizhpharm) were used, which stimulated the growth of granulation tissue.

During the staged treatment, pediatric patients complained of itching and pain, which prevented them from wearing the surgical collar. The time of preparation of wounds for autodermoplasty averaged 27.17 ± 0.18 days. Secondary autodermoplasty during staged treatment was also performed under endotracheal anesthesia. The position of the child on the operating table was similar to that of early surgical treatment. The surgeon excised the forming cicatricial roll with a bordering cut along the contours of the granulating wound, and then, the upper layer of granulation tissue was removed with a metal debrider. In the case of epithelization islets on the area of the wound surface, they were also removed with a debrider or a scalpel. The stage of autodermoplasty and dressing did not differ from the stage of autodermoplasty in early surgical treatment. Subsequently, in the postoperative period, the graft and the donor wounds were dressed in the same way as with early surgical treatment. An example of a classical staged treatment is presented in Fig. 2.

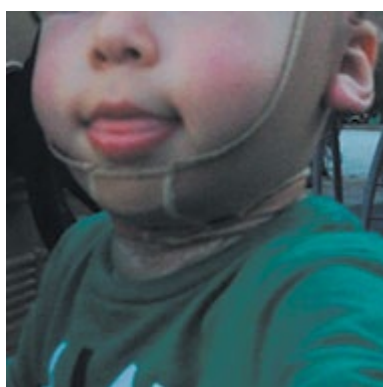


Fig. 3. Boy A., 2 years old, wearing a compression half mask

During treatment, there were no fatal outcomes in patients in both groups.

After discharge, all patients used a surgical collar for 6 months, compression garments (a half mask providing a genial-neck angle; Fig. 3), and silicone plates or anti-scar gels, and physical therapy aimed at maintaining range of motion in the neck.

A combustiologist performed the monitoring of the pediatric patients for 2 years in the outpatient department (a visit to the doctor every 3 months).

The research materials were processed using methods of parametric and nonparametric analyses. The accumulation, systematization of the initial information, and visualization of the results were performed in Microsoft Office Excel 2016 spreadsheets. Statistical analysis was performed using the Statistica 13.3 program (StatSoft Inc., Tulsa, USA). Quantitative indicators were evaluated for compliance with the normal distribution, and the Shapiro–Wilk test was used for this purpose. The significance level of the differences between the samples was determined using the nonparametric Wald–Wolfowitz test and the Mann–Whitney test (since in our study, the distribution of parameter values did not follow the normal distribution law, it was impossible to use the Student *t*-test). Nominal data were compared using the Pearson χ^2 test.

Results

The results of surgical treatment were evaluated by the indicators, namely, the number of dressings required to complete the treatment, skin restoration period as the number of days from the burn event to the removal of sutures from the graft, and the graft retention area as a percentage. Long-term results were assessed for further reconstructive interventions, and the quality of scar tissue was assessed according to the Vancouver scar scale (VSS). Data of 64 patients were examined to determine the quality of scar tissue.

Table 3 presents the early results of surgical treatment.

In the early surgical treatment of deep neck burns in pediatric patients, an average of 7.93 ± 0.45 dressings was required before the restoration of the skin; whereas in staged treatment, the number of dressings amounted to 18.75 ± 0.61 (Fig. 4). The graft retention area was $99.50\% \pm 0.13\%$

Table 3

Results of surgical treatment of pediatric patients with deep neck burns

Indices (average value)	Main group, <i>n</i> = 46 (56.8%)	Control group, <i>n</i> = 35 (43.2%)	<i>p</i>
Dressings	7.93 ± 0.45	18.75 ± 0.61	<0.001
Period of the skin restoration, days	16.54 ± 0.68	36.94 ± 0.89	<0.001
The graft pressing area, %	99.50 ± 0.13	93.91 ± 2.68	<0.001

Note. *p* — the level of significance of differences in statistical indicators in the main and control groups.

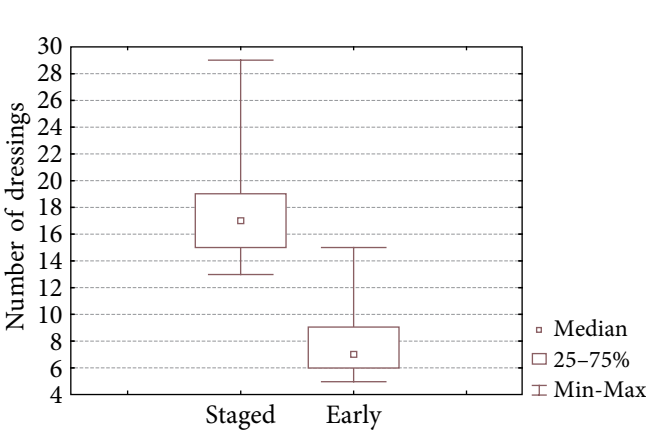


Fig. 4. Boxed graphs of the values of the number of dressings for early and staged surgical treatments. In the vast majority of cases, early surgical treatment required a smaller number of dressings (on average, eight dressings less)

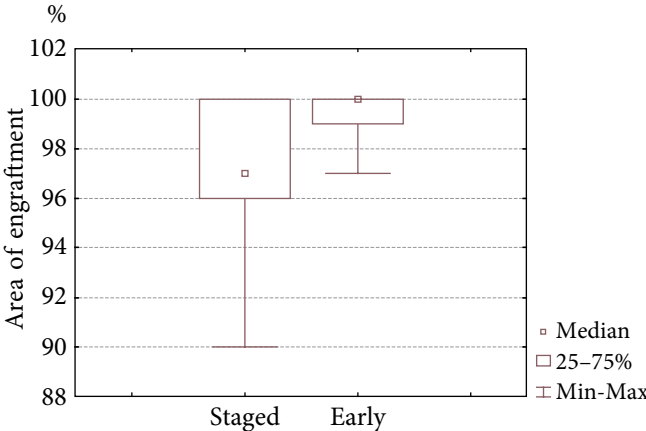


Fig. 5. Boxed graphs of the values of the area of graft retention in early and staged surgical treatments. The area of graft retention was larger in case of early surgical treatment (on average, 5% more)

in the main group and 93.91% ± 2.68% in the control group (Fig. 5). In the main group, there were no losses exceeding 5% of the graft area. In the control group, in one case, the graft lysis of 90% was registered, and because of that, repeated autodermoplasty was performed. Taking into account the data obtained, the risk of graft loss during early surgical treatment of deep neck burns was lower than during staged treatment, although not significantly. The terms of skin restoration during early surgical treatment averaged 16.54 ± 0.68 days, and in staged treatment, it lasted for 36.94 ± 0.89 days (Fig. 6).

Table 4 presents an analysis of long-term cosmetic results in pediatric patients operated for deep neck burns.

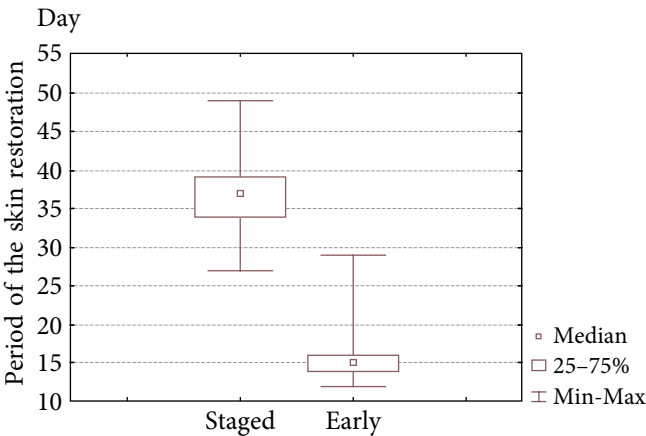


Fig. 6. Boxed graphs of the values of the skin restoration period in early and staged surgical treatments. With early surgical treatment, the skin restored much faster than with staged treatment (on average, 20 days faster)

Table 4

Scar tissue quality assessed by the Vancouver scar scale in the study and the control groups

Vancouver scar scale, points	Main group, <i>n</i> = 46 (56.8%)	Control group, <i>n</i> = 29 (45%)	<i>p</i>
Vascularization	0.73 ± 0.21	1.55 ± 0.23	<0.001
Pigmentation	1.56 ± 0.19	1.52 ± 0.09	0.484
Elasticity	1.36 ± 0.50	2.52 ± 0.31	<0.001
Height/thickness	0.35 ± 0.22	1.41 ± 0.19	<0.001
Total score	4.0 ± 0.26	7.0 ± 0.21	<0.001

Note. *p* — the level of significance of differences in statistical indicators in the main and control groups.

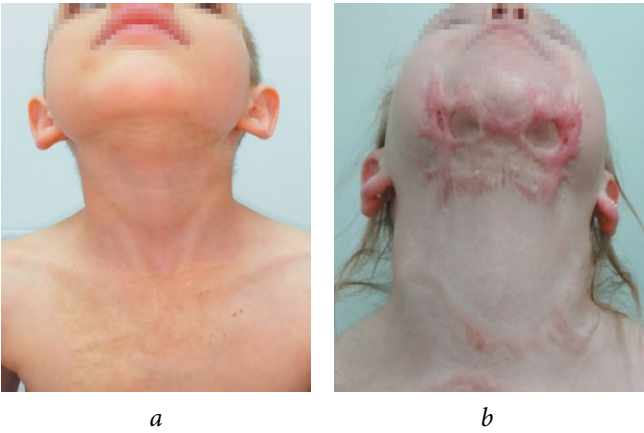


Fig. 7. The cosmetic result after treatment of a deep burn in the submaxillary space of the neck. (a) Boy G., 5 years old, after early surgical treatment (hyperpigmentation of the graft and no growth of scar tissue). (b) Girl A., 4 years old, after the staged treatment of a deep burn (proliferation of hypertrophic scar along the periphery from the graft)

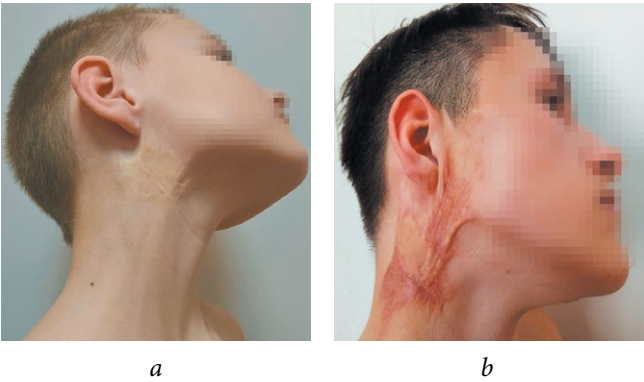


Fig. 8. The cosmetic result after treatment of a deep burn of the right lateral surface of the neck. (a) Boy Sh., 10 years old, after early surgical treatment (graft hyperpigmentation and no scar tissue growth). (b) Boy G., 13 years old, after the staged treatment of a deep burn (proliferation of a hypertrophic scar along the periphery from the graft and a traction scar in the region of the gonial angle)

Table 4 indicates that pediatric patients operated for deep neck burns in the early terms have statistically significantly better indicators of vascularization and elasticity and thickness of the formed scar tissue compared with pediatric patients who received traditional staged treatment. No statistically significant difference was revealed only in terms of pigmentation, as autografts or scar tissue were hypopigmented or hyperpigmented.

However, the total average number of points according to the VSS in the main group was significantly less than in the control group, and therefore, the cosmetic result in the main group was better (Figs. 7 and 8).

Table 5 presents the long-term results of the skin restoration in the main and control groups.

Of the 81 patients, 32 (43%) who received surgical treatment for deep neck burns required further removal of cicatricial deformities, and 49 (57%) pediatric patients did not need interventions during the 2-year follow-up period. Moreover, in the main group, post-burn contracture was registered in 12 (26%) patients. In the control group, surgical removal of the post-burn deformity was performed in 20 (57%) patients. An analysis of the data revealed a statistically significant difference in the number of pediatric patients in need of reconstructive interventions in the long-term period after the early and staged surgical treatments of deep neck burns.

Discussion

The first results of early surgical treatment of deep neck burns were obtained by Jonsson in 1991. The author reported faster terms for skin restoration in the case of early surgical treatment compared with the staged method of treatment but did not provide data on the long-term results [15]. Our study presented the advantages of surgical treatment of deep neck burns in pediatric patients 3–5 days from the moment of injury compared with the classical staged treatment (the number of dressings during the treatment were taken into account as well as the terms of the skin restoration and the area of graft retention). We were unable to find works in which cosmetic results after various methods of surgical treatment of deep neck burns would be objectively evaluated. Our study shows the best cosmetic results after the early surgical treatment of deep neck burns, which is confirmed by the VSS. According to Sharp,

Table 5

Long-term functional results of treatment

Group	No contracture <i>n</i> = 49 (57%)	Contracture <i>n</i> = 32 (43%)	<i>p</i>
Main group, <i>n</i> = 46 (%)	34 (74%)	12 (26%)	0.005
Control group, <i>n</i> = 35 (%)	15 (43%)	20 (57%)	

Note. *p* — the level of significance of differences in statistical indicators in the main and control groups.

69% of patients required surgical correction of post-burn neck deformities, and the timing and methods of restoring the skin in the acute period were not indicated [16]. In our study, the need for long-term surgical treatment arose in 32 (43%) patients, and in most cases ($n = 20$, 63%), these were pediatric patients after the staged treatment of burn wounds, which was comparable with the Voinchet data [17].

The disadvantages of early surgical treatment of deep neck burns include the complexity of the surgery itself, as the neck area in a small child is extremely inconvenient for tangential necrectomy. With radical excision of the scab, it is necessary to work carefully with an electric knife so as not to damage the platysma (any platysma injury leads to its reflex contraction, which increases the risk of the neck contracture) [18]. However, this should not be a contraindication to early surgical treatment if the patient is in a specialized department.

Conclusion

The early surgical treatment of deep neck burns in pediatric patients 3–5 days from the moment of injury, certainly, has advantages over the classical staged treatment, including a decrease in the number of necessary dressings (on average by 11 dressings) and a higher percentage of skin graft retention, with a significantly reduced period of the skin restoration (on average by 20 days). In the long term, pediatric patients who received early surgical treatment are less likely to need surgical treatment for post-burn neck deformities compared with pediatric patients who underwent staged treatment (26% of pediatric patients with early treatment and 57% with staged treatment). According to the VSS, cosmetic results are objectively better after early surgical treatment (4.0 ± 0.26 points in the main group and 7.0 ± 0.21 points in the control group).

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Legal representatives of the patients agreed voluntarily to participate in the study and publish the data.

Author contributions

P.A. Gnipov performed surgical treatment of patients, took part in the development of the study design, conducted collection and statistical processing of data and analysis of literature data, and wrote the text of the article.

A.G. Baindurashvili, *M.A. Brazol*, *E.V. Mitrofanova*, and *M.R. Melnikov* performed surgical treatment of patients, took part in the development of the study design, and edited the article text.

G.A. Mashevsky was involved in the statistical data processing and took part in the development of the study design.

All authors made a significant contribution to the research and preparation of the article and have read and approved the final version before its publication.

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