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## EFFECTIVENESS OF ANTI-SHOCK THERAPY IN THE TREATMENT OF EXTENSIVE BURNS IN CASE OF LONG-TERM COMPRESSION SYNDROME

© Nikolay K. Sokolov<sup>2</sup>, Evgeniy V. Zinoviev<sup>1, 3</sup>, Emil Ya. Fistal<sup>4</sup>, Alexander V. Semiglazov<sup>1</sup>, Eduard K. Derii<sup>1</sup>, Vladimir O. Sidelnikov von Essen<sup>1</sup>, Anna V. Kostyakova<sup>1</sup>

<sup>1</sup> Saint Petersburg I.I. Dzhanelidze Research Institute of Emergency Medicine. 3 lit. A Budapestskaya str., Saint Petersburg 192242 Russian Federation

<sup>2</sup> City Emergency Hospital. 88/35 Bodraya str., Rostov-on-Don 344068 Russian Federation

<sup>3</sup> Saint Petersburg State Pediatric Medical University. 2 Lithuania, Saint Petersburg 194100 Russian Federation

<sup>4</sup> V.K. Gusak Institute for Emergency and Reconstructive Surgery. 47 Leninsky Ave., Donetsk People's Republic Donetsk 283045 Russian Federation

**Contact information:** Eduard K. Derii — Surgeon Department of Thermal Injuries Saint Petersburg I.I. Dzhanelidze Research Institute of Emergency Medicine. E-mail: derii.eduard@gmail.com ORCID: <https://orcid.org/0000-0001-8458-0134> SPIN: 6127-4630

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**Abstract.** The article analyzes the effectiveness of the use of crystalloid and colloid solutions, antihypoxants, antioxidants, and analgesics aimed at relieving the pathological processes of shock development in patients with extensive skin burns against the background of prolonged compartment syndrome. We conducted an experimental study that included 360 adult white outbred rats of both sexes, weighing 220–240 g, divided into groups depending on the treatment method. After modeling long-term compartment syndrome in animals, third-degree burns according to ICD-10 were reproduced, with a total area of 5, 10, 15, 20, 25, 30% of the body surface. The results were assessed after the administration of crystalloid and colloid solutions, as well as any substrate antihypoxants, both based on malic and fumaric acids — reamberin, mafusol, or polyoxifyumarin. As a result of our data, the most optimal statistical group of animals in the experiment was identified, with a skin burn area of 15% and the presence of long-term compression syndrome. During the study, the optimal volume of antishock infusion therapy was determined, which exceeded the calculated volume of infusions on the first day based on the Parkland scheme by almost 40% ( $p < 0.01$ ).

**Keywords:** infusion therapy, burns, long-term compartment syndrome, shock

## ЭФФЕКТИВНОСТЬ ПРОТИВОШОКОВОЙ ТЕРАПИИ ПРИ ЛЕЧЕНИИ ОБШИРНЫХ ОЖОГОВ НА ФОНЕ СИНДРОМА ДЛИТЕЛЬНОГО СДАВЛЕНИЯ

© Николай Константинович Соколов<sup>2</sup>, Евгений Владимирович Зиновьев<sup>1, 3</sup>, Эмиль Яковлевич Фисталь<sup>4</sup>, Александр Владимирович Семиглазов<sup>1</sup>, Эдуард Константинович Дерий<sup>1</sup>, Владимир Олегович Сидельников фон Эссен<sup>1</sup>, Анна Витальевна Костякова<sup>1</sup>

<sup>1</sup> Санкт-Петербургский научно-исследовательский институт скорой помощи имени И.И. Джанелидзе. 192242, г. Санкт-Петербург, ул. Будапештская, 3, лит. А

<sup>2</sup> Городская больница скорой медицинской помощи. 344068, г. Ростов-на-Дону, ул. Бодрая, 88/35

<sup>3</sup> Санкт-Петербургский государственный педиатрический медицинский университет. 194100, г. Санкт-Петербург, ул. Литовская, 2

<sup>4</sup> Институт неотложной и восстановительной хирургии им. В.К. Гусака. 283045, Донецкая Народная Республика, г. Донецк, пр. Ленинский, 47

**Контактная информация:** Эдуард Константинович Дерий — лаборант отдела термических поражений. E-mail: derii.eduard@gmail.com ORCID: <https://orcid.org/0000-0001-8458-0134> SPIN: 6127-4630

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**Резюме.** В статье проанализирована эффективность применения кристаллоидных и коллоидных растворов, антигипоксантов, антиоксидантов, а также анальгетиков, направленных на купирование патологических про-

цессов развития шока у пациентов, имеющих обширные ожоги кожи на фоне синдрома длительного сдавления. Нами было проведено экспериментальное исследование, в которое было включено 360 взрослых белых беспородных крыс обоего пола массой 220–240 г, распределенных на группы в зависимости от методики лечения. После моделирования синдрома длительного сдавления у животных были воспроизведены ожоги III степени, общей площадью 5, 10, 15, 20, 25, 30% поверхности тела. Результаты оценивались после введения кристаллоидных и коллоидных растворов, а также любых субстратных антигипоксантов, как на основе яблочной, так и фумаровой кислот — реамберина, мафусола или полиоксифумарина. Полученные данные позволили выделить наиболее оптимальную статистическую группу животных в эксперименте, с площадью ожога кожи 15% и наличием синдрома длительного сдавления. В ходе исследования было проведено определение оптимального объема проводимой противошоковой инфузионной терапии, превышающей расчетный объем инфузий в первые сутки, исходя из схемы Паркланда, почти на 40% ( $p < 0,01$ ).

**Ключевые слова:** инфузионная терапия, ожоги, синдром длительного сдавления, шок

## INTRODUCTION

Long-term compartment syndrome or crush syndrome (CS) is a complex of pathological reactions that occur as a result of prolonged mechanical compression of soft tissues. A distinctive feature of this type of injury is the severity of clinical manifestations and high mortality [2]. A specific difference in pathogenesis is the manifestation of endogenous intoxication with products of irreversible soft tissue ischemia or the consequences of reperfusion with components of their breakdown [3]. In recent years, special attention of researchers and clinicians has been attracted by victims with extensive burns against the background of CS [1]. There are algorithms for providing specialized medical care for each of the shock conditions, but no treatment regimens in case of their combination [4]. This determines the relevance of research in this area.

## AIM

The aim of the study is to conduct an experimental analysis of the results of shock treatment using crystalloids, colloids, metabolic agents and analgesics in the acute phase of extensive burns against the background of CS.

## MATERIALS AND METHODS

The experiment involved 360 white outbred adult rats of both sexes weighing 240–250 g. CS in the experimental animals was reproduced under anesthesia by compressing soft tissues of the right or left thigh for 4 hours using special metal vices. The area of compressive surface exerted a pressure force of 8–10 kg/cm<sup>2</sup>, which corresponded to 5 cm<sup>2</sup>. After modeling ischemia, deep third-degree burns were reproduced with an area of 5, 10, 15, 20, 25, 30% of the body surface. Skin burns were performed using the fol-

lowing method: in the back, using a KDB-22 light lamp with a power of 500 W, skin was heated to 85–90 °C. Thermometry was carried out using a thermocouple sensor of Electroline multimeter (China). The exposure did not exceed 20 s.

After reproduction of combined injury, intra-abdominal administration of crystalloid or colloid solutions with metabolic correctors of antihypoxic or antioxidant action was performed. In this case, the volume of infusion therapy was carried out using the Parkland formula:

$$V = 4 \cdot M \cdot \%,$$

where V is the volume of infusion, ml; M is the body weight of the animal, kg; % is the burn area (% of the total body surface area).

Statistical processing of data was carried out in accordance with generally accepted standards in scientific research. Quantitative parameters of the study groups were compared using Student's t-test. The significance criterion was  $p < 0.05$ .

## RESULTS

The results of a comparative study of the mortality rate among animals with different volumes of infusion therapy in shock are presented in Table 1.

Analysis of the data in Table 1 leads to the conclusion that a group of animals with burn wounds of 15% of the body surface area is the most adequate model for assessing the effectiveness of intensive therapy.

The data on the comparative analysis of the mortality rate of animals relative to the area of deep skin burns are shown in Table 2. Based on them, we can conclude that the lowest mortality rate was 61.3% with volume of infusion therapy of about 100 ml/kg, which, in turn, correlated with the Parkland formula. When increasing the infusion therapy to 150 ml/kg and above, 100% mortality of experimental

animals is determined, as in the control group. The results obtained suggest that excessive infusion therapy disrupts the functioning of vital organs and functional systems.

It has been established that the probability of a fatal outcome in burn injury and long-term compartment syndrome depends on the volume of infusion therapy. The maximum survival of experimental animals with these lesions was recorded with the following infusion calculation: Volume of infusion (ml) =  $6.5 \cdot M \cdot \%$ , which, in turn, exceeds the Parkland formula by almost 40% ( $p < 0.01$ ).

Table 3 shows that administration of synthetic colloids (139 kDa) and crystalloid solutions in a ratio of 2:3 and

Table 2

**Mortality of rats with deep skin burns covering 15% of the body surface against the background of prolonged crush syndrome, taking into account the volume of infusions**

Таблица 2

**Летальность крыс при глубоком ожоге кожи площадью 15% поверхности тела на фоне синдрома длительного сдавления с учетом объема инфузий**

Table 1

**Mortality of rats with deep skin burns and crush syndrome**

Таблица 1

**Летальность крыс при глубоких ожогах кожи и синдроме длительного сдавления**

Площадь ожога, % п.т. / Burn area, % b.s.	Показатель летальности, % / Mortality rate, %	
	без лечения / without treatment	с инфузионной терапией / with infusion therapy
5	25	—
10	85	—
15	100	77
20	100	90

Объем инфузии 0,9% NaCl, мл / Infusion volume 0.9% NaCl	Показатель летальности (M±m), % / Mortality rate (M±m), %
0	100±7,1
5	92,4±9,1
10	90,7±8,8
15	77,1±9,3
20	72,3±8,1
25	63,1±8,8
30	73,1±7,4
35	79,6±9,1
40	100±10,3

Table 3

**Effect of infusions of crystalloid and synthetic colloid solutions on the mortality rate in deep burns of 15% of the body surface area against the background of crush syndrome**

Таблица 3

**Влияние инфузий кристаллоидных и синтетических коллоидных растворов на показатель летальности при глубоком ожоге площадью 15% поверхности тела на фоне синдрома длительного сдавления**

Группы наблюдения / Observation groups	Показатель летальности (M±m, %) при инфузии по формуле / Mortality rate (M±m, %) with infusion according to the formula	
	Паркланда / Parkland	условно расчетной формуле (Паркланда + 40%) / conditionally calculated formula (Parkland + 40%)
Контроль (без лечения) / Control (no treatment)	100±0	100±0
0,9% NaCl	77,1±9,3	63,1±8,8 <sup>1</sup>
0,9% NaCl + ГЭК 130 (0,8:0,2) / 0,9% NaCl + HES 130 (0,8:0,2)	41,7±6,1 <sup>1,2</sup>	54,1±7,2 <sup>1</sup>
0,9% NaCl + ГЭК 130 (0,6:0,4) / 0,9% NaCl + HES 130 (0,6:0,4)	36,4±5,9 <sup>1,2</sup>	39,3±6,7 <sup>1,2</sup>
0,9% NaCl + ГЭК 130 (0,4:0,6) / 0,9% NaCl + HES 130 (0,6:0,4)	58,1±6,2 <sup>1</sup>	62,3±7,4 <sup>1</sup>
0,9% NaCl + ГЭК 130 (0,2:0,8) / 0,9% NaCl + HES 130 (0,2:0,8)	66,2±5,6 <sup>1</sup>	77,2±8,5 <sup>1</sup>
ГЭК 130 / HES 130	86,1±7,3 <sup>1</sup>	87,1±8,1 <sup>2</sup>

**Notes.** Student's t-test: <sup>1</sup> —  $p < 0.05$  compared with the untreated group; <sup>2</sup> —  $p < 0.05$  compared with NaCl. HES — hydroxyethyl starch.

**Примечания.** t-критерий Стьюдента: <sup>1</sup> —  $p < 0,05$  по сравнению с группой без лечения; <sup>2</sup> —  $p < 0,05$  по сравнению с NaCl. ГЭК — гидроксиэтилкрахмал

crystalloids (0.9% NaCl) and synthetic colloid solutions of hydroxyethyl starch (130 kDa) in a ratio of 3:2 reduces the mortality rates of this category of animals by 40.7% ( $p < 0.05$ ) and 23.8% ( $p < 0.05$ ), respectively, compared to infusion with only physiological saline (0.9% NaCl solution).

## CONCLUSION

1. The proportion of fatal outcomes in treatment of experimental animals with mechanical and thermal injury caused by extensive burns of the skin and CS of tissue in the acute phase can be reduced by adequate infusion therapy with colloid and crystalloid solutions. It was found that in the comparison group, where adequate infusion therapy was carried out according to the conditional formula (Parkland formula + 40% of the volume of infusion therapy), a tendency to a decrease in the number of fatal outcomes was noted.

2. The solution to the issue of the effectiveness of shock treatment in the acute phase of mechanical and burn shock is directly related to the performance of adequate infusion, including combined use of crystalloid and colloid solutions. At the same time, the mortality rate in the groups studied was reduced by 1.5–2 times ( $p < 0.01$ ) compared to the group of animals where only crystalloid solutions were used.

## ADDITIONAL INFORMATION

**Author contribution.** Thereby, all authors made a substantial contribution to the conception of the study, acquisition, analysis, interpretation of data for the work, drafting and revising the article, final approval of the version to be published and agree to be accountable for all aspects of the study.

**Competing interests.** The authors declare that they have no competing interests.

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**Experiments with animals** were carried out in accordance with international rules (Directive 2010/63/EU of the European Parliament and of the Council of the European Union of September 22, 2010 on the protection of animals used for scientific purposes).

## ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ

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