Modern Views on the Surgical Treatment Tactics for Deep Electrothermal Injuries

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ABSTRACT

OBJECTIVES: To improve the treatment outcomes of patients with electrothermal lesions, we compared different surgical methods (modern vs traditional).

MATERIALS AND METHODS: In this retrospective analysis, we studied patients with electrothermal lesions who were treated in our burn department at the Republican Research Center of Emergency Medicine (Tashkent, Uzbekistan) from 2008 to 2020. During this period, 445 patients with electric shock were treated; of these, 253 (56.8%) were children.

RESULTS/CONCLUSIONS: Among the circumstances for electric trauma, most were household injuries (n = 411; 92.4%). Thirty-four patients (7.6%) had electric trauma injuries while at work. Most patients were men (n = 341; 76.6%). Of 445 patients, 326 (73.3%) had low-voltage electrical trauma, with skin lesions limited to an "electric mark." In these patients with general electrical trauma and who did not require surgical interventions for thermal tissue lesions, the main emphasis was placed on monitoring cardiovascular activity and monitoring the reaction of parenchymal organs to the effects of low-voltage electricity. For patients who needed surgery, we found that modern methods of surgical treatment for deep electrothermal lesions can shorten the time required for closure of wounds and significantly reduce the development of inflammatory complications. Better treatment can reduce length of stays in the hospital.

KEY WORDS: *Electric trauma, Shock*

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INTRODUCTION

In recent years, reasons for burn injuries have undergone significant changes. Increased sources of electricity have, of course, increased the level of comfort in life; however, they have also caused increased numbers of electrothermal injuries. Electrothermal trauma, caused by the damaging effects of electrical energy, can result in local and general changes in the body. The main factors determining the severity of electrical injuries are the type, strength, and voltage of the electric current, the duration of its exposure, and the electrical resistance of tissues.[1,2]

Over the past 10 years, the proportion of electric burns has increased from 2.7% to 8% among total types of burn injuries[3]; in developing countries, these rates are much higher, reaching 27%. Electrical injuries are characterized by a high prevalence of severe burns, which can range from 60% to 80%. Electric shock often leads to disability requiring prosthetics. The mortality rate from electric burns has not decreased in recent years but has tended to increase, ranging from 2.5% to 10%.[4,5]

Reasons for the high incidences of disability and mortality among patients with severe electrothermal burns are the result of both the lack of prevention and the need for intensive care. Care is needed for such formidable complications as multiple organ failure, burn sepsis, and burn encephalopathy. Another reason for high rates of disability and mortality in electric injuries are the high frequencies of multiple burn lesions.[6] Patient outcomes after electric injuries and electric burns largely depend on timely and adequate diagnosis and proper surgical management.[7,8]

In this study, with an aim to improve the results of treatment of patients with electrothermal lesions, we compared modern versus traditional surgical methods.

MATERIALS AND METHODS

This retrospective analysis included patients with electrothermal lesions who were treated in our burn department at the Republican Research Center of Emergency Medicine from 2008 to 2020. During this period, 445 patients with electric shock were treated; of these, 253 (56.8%) were children.

To determine indications for decompressive fasciotomy, we used the bilateral comparative dermal thermometry method. This method is based on temperature differences among the segments of the same limb. Skin temperatures in areas of deep lesion are, as a rule, 1.5 °C to 3 °C lower than temperatures of intact areas. This method was also used to determine the area of deep burns and to diagnose the severity of burn shock. To diagnose the degree and severity of bone tissue damage in deep electric burns, we used the X-Rite densitometer.

To assess the severity of burn shock, along with measuring central and peripheral hemodynamics, blood oxygenation levels, and Frank index, we used criteria such as thermometry and neutrophil-lymphocytic index.

To identify electrothermal damage to bone structures, we used the X-Rite radiography densitometer to investigate osteonecrosis zones.

Results were compared and analyzed with the use of standard statistical methods. We used the Microsoft Excel 2010 software package, including built-in statistical processing functions, for calculations. The reliability of differences between groups among quantitative parameter values was determined by *t* tests. $P < .05$ indicated statistical significance.

RESULTS

Among reasons for electric trauma, most were household injuries (n = 411; 92.4%). Thirty-four patients (7.6%) received electric trauma while at work. Most patients were males (n = 341; 76.6%).

Of 445 patients, 326 (73.3%) had low-voltage electrical trauma, with skin lesions limited to an "electric mark." In these patients with general electrical trauma and who did not require surgical intervention for thermal tissue lesions, the main emphasis of treatment was placed on monitoring the activity of the cardiovascular system and the reaction of parenchymal organs to the effects of low-voltage electricity.

The remaining 119 patients (26.7%) had electric burns of varying severity that required surgical treatment. For electrothermal injuries, electrothermal damage can also occur to bone tissue, thus significantly expanding the volume of interventions needed and lengthening the duration of surgical treatment and the duration of the postoperative period. Thus, we evaluated the results of surgical treatment of these patients with osteonecrosis (n = 16 patients) and without osteonecrosis (n = 103 patients) separately.

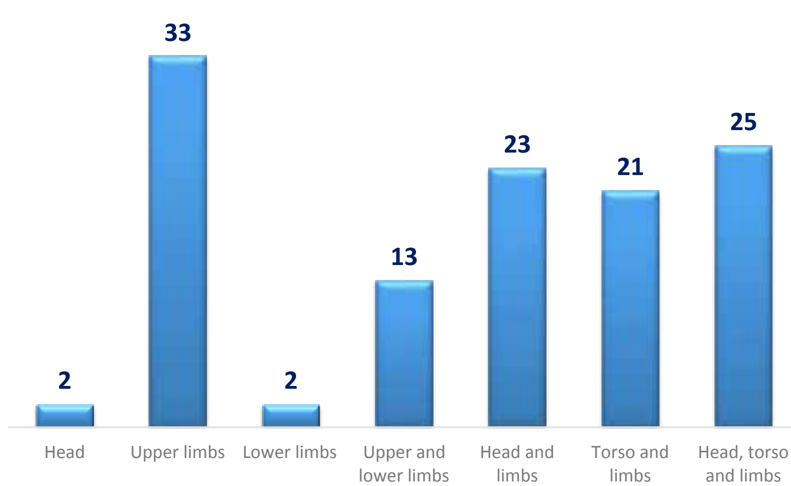
In 50 of 119 patients (42.0%) with electric burns that required surgical treatment, mild, severe, and extremely severe shock were diagnosed in 19, 20, and 11 patients, respectively.

Total lesion area ranged from 0.1% to 75% of the body surface (Table 1). Combined trauma with a fatal outcome occurred in 14 patients (3.1%).

TABLE 1. Burn Area Among Study Patients With Electrothermal Injuries

Burn Area	Study Patients (N = 445)	
	Number	Percent
Up to 10% of body area	397	89.2
11%-20% of body area	16	3.7
21%-40% of body area	15	3.3
41%-60% of body area	12	2.8
Over 60% of body area	4	1.0

FIGURE 1. Location of Burns in Patients Who Received Surgical Treatment



In the first 3 hours after injury, 352 patients (79.1%) were admitted to the specialized care unit of the Republican Research Center of Emergency Medicine; approximately 1 in 5 patients (n = 93; 20.9%) were admitted to the clinic later than 3 hours after electric injury.

In patients who had general electrothermal trauma with skin lesions in the form of a "mark," patients had thermal damage isolated to the fingers and hands. In the 119 patients with electric burns who required surgical treatment, 38 patients (31.1%) had isolated lesions of the head (n = 2), upper extremities (n = 33), and lower extremities (n = 2). In all other cases, multiple and/or widespread burns of 2 or more anatomic zones were diagnosed (Figure 1). Most patients had Frank index values up to 30 units (Table 2).

Another important point of electrical injuries, as is known, is the high frequency of combined mechanical injuries due to falling from a height, hitting hard objects, and convulsive muscle contraction. In the 119 patients with electric burns requiring surgery, 52 patients had traumatic brain injury, 3 patients had chest injuries, 2 patients presented with damage to the abdominal organs, 48 patients had bruised and lacerated skin wounds, and 11 patients had skeletal bone fractures. In addition, in the same group, 8 patients had thermo-inhalation damage to the respiratory tract and 5 had carbon monoxide poisoning.

All patients received traditional drug therapy, with volume and composition depending on the severity of the condition, the timing of admission to the hospital, the period of burn disease, and the presence of complications. Traditional treatment of electrothermal trauma included infusion therapy, the use of drugs to improve blood rheology, glucocorticoids, protease inhibitors, drugs to improve cardiac and respiratory activity, analgesics, neuroleptics, hepato-protectors, antioxidants, and antibacterial therapy. If necessary, patients also received transfusion of blood, plasma, and albumin. Local treatment of wounds was carried out with the use of wet-drying and ointment dressings, depending on the phase of the wound process, including drying of necrotic tissues using gauze wet-drying dressings with antiseptic solutions (iodopovidone, iodopyrine, betadine) or dressings with multicomponent ointments having water-soluble basis.

TABLE 2. Frank Index Results in Study Patients

Frank Index	Study Patients (N = 445)	
	Number	Percent
Up to 30	413	92.8
31-60	17	3.8
61-90	11	2.5
Over 90	4	0.9

We found that temperature differences between the armpit and the interdigital space of the foot of 0.5 °C to 1.5 °C corresponded to a mild degree of burn shock; severe and extremely severe burn shock showed temperature differences in these zones of 1.6 °C to 4 °C and above 4 °C, respectively.

We also used this technique to assess the depth of electrothermal damage to limb tissues. Therefore, if the skin temperature above the affected area of the limb compared with the corresponding segment of the unaffected contralateral limb was lower by 1.5 °C to 3 °C, then there was a high degree of probability to assume the presence of a deep burn involving muscle structures, allowing care for early fasciotomy before the development of obvious signs of the sheath syndrome and complications to regional blood flow of the limb segment. Among patients requiring surgical procedures, according to the results of bilateral comparative thermometry, early decompressive fasciotomy was performed in 34 patients in the first 12 hours after electrothermal trauma. In all 34 patients, damage to the underlying muscle tissue was confirmed intraoperatively, including 31 involving the neurovascular bundle, which indicated the validity of preventive fasciotomy and the informative need for bilateral comparative thermometry.

The progression of oxidative stress is known to be facilitated by acute ischemia of the affected limbs, which occurs in patients with electrothermal trauma, usually as a result of case syndrome.

An important component of surgical treatment of victims with subfascial electroburning is decompressive fasciotomy on the extremities early after injury (6-12 hours after injury). This can prevent the development of vascular thrombosis and secondary ischemic limb lesions due to the development of subfascial edema. Indications for this operation are an increase in the volume of the limb segment, the absence or weakening of pulsation of the main vessels, a change in the color of the skin of the limb segment (pallor, cyanosis, marbling), a decrease or absence of tactile or pain sensitivity, and any suspicion of damage to the main vessels. A more accurate and early diagnosis of the depth of the lesion and the determination of indications for fasciotomy can be facilitated by bilateral comparative thermometry of the extremities.

In 52 patients, fasciotomy was performed later than 24 hours after injury; reasons were because of late admission of patients to a specialized department. Fasciotomy, which is a type of necrotomy of deep burns, was limited to dissection of the fascia within the bottom of the burn wound.

Recently, we have been following modern, early surgical tactics, that is, performing decompressive expanded fasciotomy in the first 6 to 12 hours after patient admission to the clinic and early and early/delayed necrectomy performed by the end of the first week after electrothermal trauma. We used a similar approach in 51 patients with electric burns. Fasciotomy was performed as an independent operation before the development of clinically pronounced subfascial edema, and the extent and zones of fasciotomy were determined by the results of bilateral comparative thermometry. When the extent of the fasciotomy went beyond the burn wound, an attempt was made to dissect the fascia over each muscle group of the affected limb. Patients in this group were treated with synthetic temporary wound coverings after necrectomy. Ingredients for wound coatings included Parapran dressing with chlorhexidine, Parapran dressing with chymotrypsin, Voskopran dressing with dioxydine, Voskopran dressing with levomekol, and Voskopran with methyluracil ointment. When electric burns were combined with burns by the flame of a voltaic arc or tanned clothing, in the early periods after the injury, Parapran dressing with lidocaine and Gelepran dressing with lidocaine were used.

Early expanded fasciotomy on the first day of the injury, earlier necrectomy 6.8 ± 2.1 days after injury, and the use of synthetic temporary wound coverings made it possible to perform the final stage of surgical treatment (auto-dermoplasty) 1 week earlier (compared with patients who received traditional surgical treatments), the staging of which depended on the area of deep burns.

Modern surgical tactics contributed to improved engrafting ability of autografts (95.2% vs 87.4%), reduced frequency of repeated auto-dermoplasty procedures at the sites of non-implantation by 2.6 times, significantly reduced frequency of crippling operations (amputation and exarticulation of limbs) from 55.8% to 9.8%, and reduced duration of inpatient treatment from 41.1 ± 12.3 to 37.7 ± 10.4 days (Table 3).

In patients with osteonecrosis of electrothermal etiology, our approaches to choosing the optimal timing of surgical treatment differed significantly from those with soft tissue burns. The traditional management of patients with osteonecrosis was surgical treatment of necrotic bone tissue performed 3 to 5 weeks after electrothermal trauma. In addition, with osteonecrosis of the bones of the cranial vault, the zone of primary intervention was often limited to processing only the outer plate. In patients with osteonecrosis of tubular bones, tangential osteo-necrectomy was often performed insufficiently due to the lack of information about the clear boundaries of osteonecrosis. The operation itself was multistage in nature, and the subsequent stages were started after the natural, spontaneous rejection of the remaining areas of osteonecrosis and after the appearance of granulation tissue in these areas. These factors significantly lengthened the overall duration of inpatient treatment, and each repeated (staged) osteo-necrectomy represented an additional stress factor for the patient.

Our radiographic densitometric studies showed that the mineral density of normal bone was 0.62 ± 0.06 conventional units (CU), whereas in the focus of osteonecrosis, the mineralization index gradually decreased to 0.23 ± 0.02 CU within 10 to 14 days after injury and subsequently remained within these values. Only after the osteo-necrectomy, in the regeneration phase (12-15 days after the intervention), this indicator rose to 0.44 ± 0.05 CU.

Radiographic densitometry results showed that, 2 weeks after the electrothermal trauma, the process of demineralization of the affected bone tissue was completed. This fact indicates the completion of the progression of post-traumatic osteonecrosis by this time. This observation allowed us to revise the traditional approach to choosing the optimal term of osteo-necrectomy and to simultaneous apply radical osteo-necrectomy over the entire surface of osteonecrosis in 18 patients already 2 to 3 weeks after the injury (that is, 1-3 weeks earlier). As a rule, there are still

TABLE 3. Timing of Surgical Interventions and Results of Surgical Treatment of Patients With Electric Burns Without Damage to Bone Structures

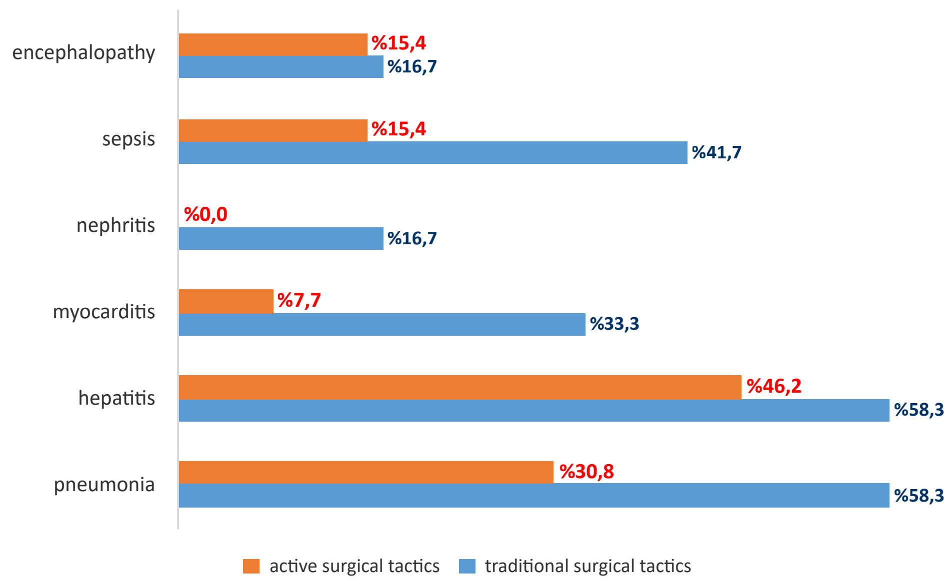
Parameter	Traditional Surgical Treatment (n = 52)	Modern Surgical Treatment (n = 51)
Decompressive fasciotomy, days	3.0 ± 1.0	1.0 ± 0*
Necrectomy, days	13.6 ± 6.1	6.8 ± 2.1*
Auto-dermoplasty, days	27.6 ± 12.0	20.9 ± 5.7*
Survival rate of autografts, %	87.4	95.2
Amputations and exarticulations of the limb, No. (%)	29 (55.8)	5 (9.8)**
Duration of inpatient treatment, days	41.1 ± 12.3	37.7 ± 10.4

*$P < .05$ compared with group having traditional surgical treatment.

**$P < .001$ compared with group having traditional surgical treatment.

FIGURE 2. Imposition of Multiple Milling Holes With Osteo-Necrectomy of the Frontal and Parietal Bones on the Right

FIGURE 3. Burn Disease Complications Shown With Type of Surgical Treatment



no signs of osteomyelitis, and, in patients with lesions of the bones of the cranial vault, there are signs of intracranial purulent-inflammatory complications.

The desire to comply with the principle of early simultaneous radical osteo-necrectomy prompted us to improve osteonecrosis surgery of the bones of the cranial vault. With lesions of up to one-third of the area of the cranial vault, the entire wound surface was treated at once, applying the milling holes more closely (0.5 cm) to each other (Figure 2).

In general, with the use of modern surgical tactics, complications were notably decreased; in particular, septic complications decreased by 2.7 times (Figure 3).

DISCUSSION AND CONCLUSIONS

The use of modern surgical treatment methods for deep electrothermal lesions can shorten the time required for closure of wounds and significantly reduce the development of inflammatory complications. With better and more effective treatments, the length of hospitals stays can be reduced in this patient population.

The modern tactic of early fasciotomy on the first day of injury and early necrectomy (by 6.8 ± 2.1 days after injury) contributed to a significant reduction in the frequency of crippling operations (amputation and exarticulation of limbs) from 55.8% to 9.8%, allowed auto-dermoplasty to be conducted 1 week earlier (compared with traditional tactics), improved engrafting ability of autografts from

87.4% to 95.2%, and reduced the duration of inpatient treatment from 41.1 ± 12.3 to 37.7± 10.4 days.

According to radiographic densitometric studies, the process of osteonecrosis in electrothermal trauma is completed within 2 weeks after the injury, allowing osteo-necrectomy to be started 1 to 3 weeks earlier, including simultaneous radical osteo-necrectomy over the entire surface of osteonecrosis. An increase in the radicality of osteo-necrectomy in osteonecrosis of the bones of the cranial vault was achieved by a closer overlap (0.5 cm apart) of the milling holes on the entire wound surface.

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