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Local complications of residual upper and lower limbs in combatants

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Introduction. Contemporary combat limb injury is characterized by massive soft tissues and bone structures, which often makes it impossible to save the injured extremity and need for its amputation. However, a number of amputees have pain syndrome in the residual limb and cannot use prostheses.

Objective. To analyze local complications, causes of residual limb pain syndrome, and methods of their treatment.

Methods. We observed 285 combatants with residual limb pain syndrome after its combat injury, of which 151 (53%) had neuromas and 108 (38%) had heterotopic ossification and osteophytes. All individuals were male. The average age was 36.1±8.6 years. The intensity of the pain syndrome according to the Defense and Veterans Pain Rating Scale (DVPRS) ranged from 4 to 10 points.

Results. Treatment of persistent pain in the stump with analgesics was not effective. Denervation of neuromas using alcohol injections, performed in 69 (24.2%) patients, was effective in pain syndrome intensity up to 6 points on the DVPRS scale. Neuroma resection was effective in 77% of patients, but sensitization persisted in 23%. Recurrent pain syndrome with lower intensity was observed in 30% after neuroma resection, nerve stump compression with cautery and alcohol blockade. Addition these procedures with the nerve stump suture, reduced neuroma recurrences by up to 10%. The best results of surgical treatment of neuromas with pain syndrome of 6 points and more on the DVPRS scale were obtained after their resection and the use of regenerative peripheral nerve interface (RPNI) in 25 patients. These patients had no recurrence of pain syndrome within 2 months after surgery. Heterotopic ossification most often occurred in patients with mine-explosive injuries in the thigh stumps 2-6 months after limb amputation and recurrence after simple resection of osteophytes. After performing myodesis in 18 patients there was no recurrence of heterotopic ossification within a year of observation.

Conclusions. Neuromas of peripheral nerves and heterotopic ossification are the main causes of pain syndrome in late period after amputation in combatants with residual limbs. The most effective methods of surgical treatment of neuromas in residual limbs is neuroma resection and regenerative peripheral nerve interface. Myodesis prevents the formation of heterotopic ossification.

Keywords: limb amputation, peripheral nerve neuroma, heterotopic ossification, regenerative peripheral nerve interface, myodesis.
Introduction

The ten-year experience of the war in Ukraine allows us to analyze certain consequences of combat trauma in the military, particularly limb injuries. Literature provides data on the treatment of combat limb trauma and immediate and late complications based on the materials of the war in Iraq and Afghanistan, as well as during local military conflicts. Modern combat limb trauma is more severe, characterized by massive soft tissue and bone injuries, which often makes it impossible to save the injured limb or purulent-necrotic complications occur, which are life-threatening and require amputation [1]. The majority limb amputations in the cases of combat injuries are performed urgently at the second role of medical care and are of the primary debridement nature. The final formation of the stump in such patients and the restoration of residual limb function create significant challenges to surgeons, prosthetists and rehabilitation specialists.

In 2016, R.A. Hyada et al. (2016) analyzed a quality of life of combatants after severe combat trauma of the lower extremities sustained in the Iraq and Afghanistan, which showed better outcomes in those injured who had limbs amputated than those in whom the limbs were preserved [2]. However, it should be noted that 20-40% of the injured have infectious complications in the amputation stump [3], and 63-65% have heterotopic ossifications [4, 5]. Some amputees cannot use prostheses due to residual limb pain syndrome [6], which M.H. Ebrahizadeh and S. Hariri (2009) observed in 42%, and H.E. Bourke et al. (2011) observed in 70% [7, 8]. Residual limb pain syndrome significantly reduces the quality of life for many wounded combatants with amputated limbs. E.E. Low et al. (2017) analyzed 2879 patients who underwent lower limb amputations after traumatic injuries and found a high rate of complications, and 41.8% of them requiring at least one revision amputation [9].

The most common cause of pain syndrome is neuromas of major or superficial nerves in the residual limb. To reduce pain syndrome, S.C. Linton et al. (2024) recommend performing intraoperative cryoablation, which should provide effective analgesia [10].

Materials and Methods

Our study included 285 servicemen with amputated upper or lower limb after combat injury and with residual limb pain syndrome, who were treated during 2022-2023 years. Patients, who had minor pain in the residual limb, as well as isolated phantom pain and phantom sensations, were not included in the sample. All patients were male. The average age was 36.13±8.64 years.

There were 9 (3.2%) lower leg amputations, 57 (20.3%) middle leg amputations, 42 (14.8%) upper leg amputations, 28 (9.3%) lower thigh amputations, 55 (19.3%) middle thigh amputations, 15 (5.3%) upper thigh amputations and 1 (0.4%) – disarticulation. Amputations at various levels of the forearm included 3 (1%) at the lower third, 10 (3.5%) at the middle third, 13 (4.6%) at the upper third, 23 (8.2%) at the lower third of the arm, 15 (5.3%) at the middle third of the arm, 4 (1.4%) at the upper third of the arm, and 3 (1%) shoulder disarticulations. Amputations at different levels of the foot were observed in 7 patients (2.5%). Ten patients (3.5%) had two lower limbs amputated, 4 patients (1.4%) had bilateral upper limbs missing. 13 patients (4.6%) had local complications of amputation stumps with signs of infection. False stumps made prosthetics impossible in 12 (4.2%), excess soft tissue – in 6 (2.1%), inconvenient amputation level – in 48 (16.8%), deep infection and stump ulcer – in 2 (0.7%), neuromas – in 151 (53%), heterotopic ossification and osteophytes – in 108 (38%).

Results and Discussion

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

The cause of the pain syndrome in the early period after limb amputation was stump swelling, local infectious complications and soft tissue necrosis. These complications occurred more frequently in individuals who had neurovascular injuries and compartment syndrome, which correlates with studies by E.E. Low et al. (2017), who observed local stump complications three times more often in patients with compartment syndrome [9]. Therapeutic procedures, surgical and drug treatment in such cases was effective.

Neuromas and heterotopic ossification were the main causes of late local complications, which were accompanied by a pain syndrome and made it impossible to use prosthesis.

In addition to a general clinical examination, the pain syndrome was assessed using The Defense and Veterans Pain Rating Scale (DVPRS), which was created in 2010 to assess the intensity of acute and chronic pain among wounded
military personnel and veterans and is used in hospitals of the Veterans Health Administration USA [11]. This scale includes a basic color code, visual facial expression assessment, and verbal descriptors. Green indicates mild pain on a scale of 0 to 4, yellow indicates moderate pain on a scale of 5 to 6, and red indicates severe pain on a scale of 7 to 10. The basic color code is supplemented by a verbal descriptor scale: 0 – no pain, 1 – hardly notice pain, 2 – notice pain does not interfere with activities, 3 – sometimes distracts pain, 4 – distracts me pain, can do usual activities, 5 – pain interrupts some activities, 6 – hard to ignore avoid usual activities, 7 – pain is the main focus of attention, prevents doing daily activities, 8 – awful pain, difficult to do anything, 9 – cannot bear the pain, unable to do anything, 10 – as bad as it could be, nothing else matters.

The intensity of pain in the amputated limb according to the DVPRS scale in our patients was from 4 to 10 points. 101 patients (36.4%) had somatic pain in the stump, 114 patients (41.1%) – had neuropathic pain in the residual limb. The nature of neuropathic pain syndrome was determined based on the results of neurological examination. In 63 (22.5%) patients, the pain syndrome was caused by both somatic and neuropathic reasons. (Fig. 1).

![Figure 1. The pain syndromes structure in the residual limb among combatants after amputation](image)

Ultrasonography of the residual limb was the main diagnostic method for localization of peripheral nerves terminal neuromas, assessing their relation to soft tissues and bone structures, involvement in scar tissue, and presence of inflammatory changes. X-ray examination of the residual limb allowed for the detection of osteophytes, heterotopic ossification, the amount of excess or deficiency of soft tissues and to diagnose of a residual limb deformity.

Treatment of persistent pain in the residual limb with analgesics was not effective. This created the conditions for search other treatment strategies.

Denervation of neuromas using alcohol injections were performed in 69 patients (24.2%), of which 43 performed for primary indications and 26 had recurrent pain after neuroma resection. Repeated lidocaine-alcohol injections for painful neuromas were performed in 6 patients (8.7%). Alcohol induced chemical neurolysis due to Wallerian degeneration and inhibited neurotransmission. Three to six months after lidocaine-alcohol injections, neuropathic pain in the residual limb was significantly lower. However, for severe pain syndrome, more than 6 points on the DVPRS scale, injection techniques were not effective.

Primary resections of terminal neuromas were performed in 82 patients. From 1 to 4 terminal neuromas of peripheral nerves were removed from each of them (Fig. 2).
Regardless of the resection technique, 77% of patients noted a reduction in pain sensations and improvement in quality of life after surgery. However, persistence of sensitization was observed in 23% of cases.

In 27 patients after resection of neuroma, the stump of the nerve was crushed with a clamp, cautery and alcohol block were performed. Among them, in 8 (30%), a recurrence of painful terminal neuromas was observed with a pain intensity of less than 6 points on the DVPRS scale. These patients subsequently underwent alcohol denervation under ultrasound control with good clinical effect.

In 30 patients after neuroma resection, the nerve stump was crushed with a clamp, cautery, alcohol block, and nerve suture were performed. In this group, recurrent painful terminal neuromas with pain intensity less than 6 points on the DVPRS scale occurred in 3 (10%) cases, for whom subsequent alcohol denervation under ultrasound control was performed.

The best results of surgical treatment of neuromas were obtained with the use of regenerative peripheral nerve interface (RPNI) in 25 patients with terminal neuromas and a pain syndrome of 6 points or more on the DVPRS scale.

The surgical technique involved neuroma resection and the immersion of the transected nerve in the autologous free muscle flap. (Fig. 3).

This method was developed by a team of surgeons at the University of Michigan between in 2016-2021 to enhance the transmission of nerve signals from an amputated limb to a neuroprosthesis. It has also shown effectiveness in preventing the formation of secondary painful neuromas at the residual limb. Observation of our patients for 2 months after the surgery did not reveal a recurrence of the pain syndrome.
Heterotopic ossification is the growth and ossification of mesenchymal cells from the bone marrow, which spread into soft tissues near periosteum around the amputated bone [12, 13].

The mechanism of heterotopic ossification is not been fully elucidated. Massive soft tissue damage, muscle ischemia, bone fragments, devitalized tissues, hematoma and infection are known to contribute to heterotopic ossification [14]. Mitchell EJ et al (2010) suggest that genetic factors influence the development of heterotopic ossification [15]. The risk of heterotopic ossification formation in the residual limb in our patients depended on the mechanism of combat trauma and the level of amputation. Most often, heterotopic ossification developed in individuals after mine-explosive injury and in residual limbs at the hip level.

The timing of the development of this complication, with which amputees applied, was from 2 to 6 months after limb amputation (Fig. 4).

![Figure 4. Heterotopic ossification of the femoral stump](image)

We did not find a dependence between the development of heterotopic ossification and the number of surgical interventions in the wounded, but all these patients had severe and massive tissue damage in the amputated limb. A possible favorable factor in the development of heterotopic ossification may be multiple surgical procedures and long-term wound treatment with negative pressure therapy.

However, these methods were used in cases of significant tissue damage in the wounded and complicated wound healing, which may be the main reason for the development of heterotopic ossification.

Heterotopic ossification caused pain syndrome and the inability to use a prosthesis. The traditional method of treating of this complication was the removal of bony growths, therapy with non-steroidal anti-inflammatory drugs, and X-ray therapy. However, in 8 patients, after the removal of osteophytes, recurrence of heterotopic ossification occurred, which required repeated surgery.

The risks of heterotopic ossification can be reduce by careful rounding of the femur, minimal soft tissues traumatization, avoiding hematomas, and prevention of wound infection [16].

A promising method for preventing heterotopic ossification after transfemoral amputation is myodesis (Fig. 5).
The technique involves circular thigh adductor muscle fixation to the femoral stump, using transosseous sutures with immersion of the muscle into the bone marrow canal. This prevents excessive hip abduction and flexion by the abductor muscles, creates a dynamic muscle balance, and improves prosthesis fit and function. Observations of our 18 patients for a year showed that they did not have heterotopic ossification after myodesis.

In conclusions: The causes of pain syndrome in the early period after limb amputation are stump swelling, local infectious complications and necrosis of soft tissues, which are effectively treated by surgical methods in combination with therapeutic procedures and medications. The most effective surgical procedure for treating symptomatic painful terminal neuromas is the regenerative peripheral nerve interface. Myodesis is a promising method of heterotopic ossification prevention and its recurrence after transfemoral amputation.

References


