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HEALTH, ENVIRONMENT, DEVELOPMENT**COMPARTMENT SYNDROME AS A CONSEQUENCE OF FIREARM INJURIES****Valentyna Chorna**

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Summary

At present, the problem of compartment syndrome remains relevant due to military actions in Ukraine. The pathogenesis of this syndrome lies in the increase of subfascial pressure in the osteofascial compartment, which disrupts innervation and blood supply. Along with this, muscle swelling of up to 30–50% occurs, causing additional pressure and complications. Compartment syndrome in the case of firearm injuries of the limbs occurs in 55.0% – fractures of the tibia, 39.0% – femur, 3.4% – forearm, 3.4% – foot bones. Since the beginning of the war in the east in 2014, the frequency of firearm injuries to the limbs has been 65.0% compared to torso injuries up to 20%. Delayed diagnosis or treatment of compartment syndrome can lead to disability, as irreversible nerve damage and muscle atrophy occur, with a mortality rate of about 50%. Also, with untimely assistance, the frequency of limb amputations is about half of the cases. The main and effective method of treatment is fasciotomy, but it also has certain complications with incorrect or delayed treatment. For example, the execution of fasciotomy with violations: 31.0% – fasciotomy of only one compartment of the affected segment, 27.0% – fasciotomy that did not have a decompressive effect, and others. To reduce complications including the formation of ischemic contracture (acute period – reactive-restored, residual period); neurodystrophic disorders; pseudarthrosis, osteomyelitis; delayed fracture consolidation, formation of pseudoarthrosis; patient death, timely diagnosis of compartment syndrome

using magnetic resonance imaging, ultrasound, etc., is necessary. In our study, 3 clinical cases of compartment syndrome of the limbs with successfully performed fasciotomy are presented. As a result, patients have a positive prognosis due to timely diagnosis and treatment.

Key words: fasciotomy, acute compartment syndrome, chronic compartment syndrome, subfascial pressure, compartment pressure.

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1. Introduction

Compartment syndrome arises due to increased pressure within the compartment and muscle swelling pressing on the fascia excessively. Normally, there is a small amount of fluid in this space, which facilitates muscle contraction and relaxation within the fascia. Therefore, there is no room for additional fluid or pressure. Most commonly affected by gunshot injuries are: the proximal third of the tibia or forearm bones, muscles, nerves, leading to the formation of a hematoma between the layers of fascia at the site of injury, resulting in increased subfascial pressure, vessel spasm, ischemia within 4 hours, endothelial damage to capillaries, tissue swelling, muscle necrosis due to untimely medical intervention.

2. Materials and Methods

Review of literature sources PubMed, Google Scholar, Scopus, Medline and search queries: “Compartment Syndrome” for the last 5 years. Clinical cases and medical histories of servicemen of the Armed Forces of Ukraine (AFU) with compartment syndrome due to injuries sustained during task performance were considered.

3. Results

We conducted an analysis and study of various treatment methods for servicemen of the AFU with compartment syndrome, their effectiveness, and possible further complications. In Figure 1, one of the cases of multiple gunshot shrapnel, blind left shin injury with the development of compartment syndrome in a serviceman of the AFU is depicted (Figure 1).



Fig. 1. Clinical Case: Multiple Gunshot Shrapnel Blind Injury (MGSBI) of the left shin with the development of compartment syndrome

In this case, the patient underwent timely fasciotomy, which prevented further complications.

In the following Figure 2, to alleviate compartment syndrome, the patient underwent open fasciotomy of the muscle compartments.



Fig. 2. Clinical Case: Decompressive open fasciotomy of muscle compartments performed

For the development of compartment syndrome, the minimal pressure threshold is 30 mmHg (normal pressure is 10 mmHg). This causes compression of muscles and vessels, accompanied by ischemia. Therefore, in this case, decompressive open fasciotomy was performed due to the high pressure level.

In the next case (Figure 3), along with fasciotomy, incision of the carpal ligament was performed due to damage to the vascular-nerve bundle. Thanks to timely fasciotomy, complications for the serviceman of the Armed Forces of Ukraine (AFU) were avoided, as the patient already had damage to the vascular-nerve bundle, which could have led to rapid ischemic development.



Fig. 3. Clinical Case: Gunshot bullet through-and-through injury to the right forearm with damage to the vascular-nerve bundle (VNB) and gunshot fracture of both forearm bones. Primary surgical wound debridement (PSWD) performed, radial artery ligated, external fixation device applied. Open fasciotomy of the compartments of the right forearm, incision of the carpal ligament

The process of fasciotomy includes:

Incision of the affected area. The British Orthopaedic Association and the British Association of Plastic and Reconstructive Surgeons recommended a two-incision technique, which includes anterolateral and posteromedial incisions.

Complete removal of all necrotic tissues.

Preservation of vital structures.

Wound debridement.

Therefore, it is worth noting that fasciotomy is the leading method for treating compartment syndrome. The sooner this surgical intervention is performed, the fewer complications the patient will face. This is because ischemia of the muscles and subsequent necrosis can lead to life-threatening conditions.

4. Discussion

According to the studies by Bodansky D. (*Bodansky, 2018: 1699*) and Osborn C. P. (*Osborn, 2020*), acute compartment syndrome manifestations occur spontaneously with rapid symptom development, and the influence of excessive physical exertion cannot be ruled out. This can lead to irreversible changes in muscles, paralysis, and fatal outcomes.

According to the research of Vogels S. (2020) and Callender N.W. (2022), chronic compartment syndrome develops slowly, and in this case, it often occurs during physical activities. Thus, professional athletes are at risk due to excessive muscle loads. Although this condition is not an emergency, it causes significant discomfort.

According to Zhang D. (*Zhang, 2020: 22*), the severity levels of compartment syndrome are classified as follows:

Mild: with normal blood flow in major vessels. Possible paresthesia or hypoesthesia of the fingers. Subfascial pressure is 30–40 mmHg lower than diastolic arterial pressure or approaching it.

Moderate: with normal blood flow in major vessels. The affected limb is cool, cyanotic, weak pulse, possible hypoesthesia or anesthesia of the fingers. Subfascial pressure is equal to or greater than diastolic pressure.

Severe: with impaired blood flow in major arteries. The affected limb is cold, pale, absent pulse, fingers are anesthetized. According to the studies by Pechar J., Lyons M. M. (*Pechar, 2016: 265*), the main clinical symptoms, known as the “6 Ps”, are:

- Paresthesia
- Poikilothermia (temperature difference in the affected limb)
- Pain
- Paralysis
- Pallor
- Pulselessness.

The gold standard for diagnosing compartment syndrome is magnetic resonance imaging, where diffuse swelling is observed. The fascia swells laterally and may be thickened. Additionally, a swelling-like signal is observed in the subcutaneous fat adjacent to the fascia, indicating additional pressure (*Elliott, 2003: 625*).

Authors Osier C. and colleagues (*Osier, 2018: 105*), as well as Rickert K. D. and colleagues (*Rickert, 2018: 434*), indicate that the most effective treatment method is emergency surgical fasciotomy. In combination, orthopedic, vascular, and plastic surgery may be used to address accompanying injuries. It is essential to perform combined/open fasciotomy with subsequent revision of the vascular-nerve bundle to prevent complications. It is necessary to consider the severity levels, as treatment will vary, namely: for mild cases, subcutaneous fasciotomy is performed; for moderate cases, combined fasciotomy; for severe cases, dermofasciotomy, revision of the vascular-nerve bundle, necrotomy, and secondary wound closure are necessary.

According to Gamulin A. (*Gamulin, 2022: 103*), it is important in the treatment of compartment syndrome to delay wound closure until 7–10 days later. There is an opinion that it is better to leave the wounds open for delayed primary closure. Wound irrigation is typically required 2–3 days after surgery. However, intermediate coverage is used, namely simple absorbent dressings and semi-permeable membranes.

According to the research by Gordon W. T. (*Gordon, 2018*) and Sigamoney K. (*Sigamoney, 2015*), essential in pharmacological treatment is the assessment of hypovolemia, metabolic acidosis, and myoglobinemia to prevent possible renal failure. Detoxification/anti-oxidant solutions and solutions to improve blood rheological properties, diuretics, analgesics, nonsteroidal anti-inflammatory drugs, and additional oxygen may be needed. It is important to maintain normal blood pressure, as hypotension can further decrease tissue perfusion, leading to tissue damage.

In the presence of acute compartment syndrome, it may be necessary to conduct investigations for rhabdomyolysis, including the following indicators:

- Creatine phosphokinase (CPK)
- Renal function tests
- Urinalysis
- Urinary myoglobin

According to Elliott K. G. (2003), magnetic resonance imaging (MRI) is proposed as the gold standard for diagnosing compartment syndrome, where diffuse swelling and swelling-like signal throughout the lateral compartment are observed. The fascia may be slightly thickened. Additionally, a swelling-like signal is observed adjacent to the fascia in the subcutaneous fat.

As a simple and accessible method of instrumental diagnosis, Khan S. K. (*Khan, 2011*) considers ultrasound (US) in compartment syndrome, where the presence of hematomas between the quadriceps muscle and the anterior surface of the femoral shaft can be observed.

According to Donaldson J. (*Donaldson, 2014*) and Schmidt A. H. (*Schmidt, 2017*), it is necessary to measure intra-compartmental pressure, with the sensor fixed at a distance of 5 cm from the injury zone. The anterior compartment is the most affected and accessible in the leg, and pressure measurement in this compartment is often prioritized. All compartments of the affected limb should be examined if necessary.

Non-pharmacological local interventions require the elimination of external compressive forces and the removal of all constrictive dressings. The affected limb should be kept “at heart level” and not elevated. Avoiding positional compression and controlled cooling of the affected muscle compartments (with cool water) will provide temporary relief and time for evacuation.

5. Conclusions

Therefore, timely performance of fasciotomy, depending on the severity of the condition and complications from combat trauma (combined, multiple), is crucial for a positive prognosis for the patient and reducing potential complications such as ischemic contracture, neuro-dystrophic disorders, pseudarthrosis, osteomyelitis, and formation of a false joint. According to statistics, this surgical intervention reduces the risk of limb amputation, highlighting the importance of rapid diagnosis and proper treatment approach.

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