

To Conduct A Comparative Assessment Of The Dynamics Of Tissue Microcirculation In Uncomplicated Post-Traumatic Period

Jo'raev Ruslan Sayfulloevich., Akramov Vohidjon Rustamovich

Bukhara State Medical Institute Named After

Abu Ali Ibn Sino. Bukhara, Uzbekistan.

e-mail: akramov.vohidjon@bsmi.uz

Abstract. Distal forearm fractures are among the most common injuries of the musculoskeletal system, accounting for a large proportion of upper limb trauma. Distal radius fractures represent the majority of these injuries and frequently occur in middle aged and elderly patients, often associated with osteoporosis and minimal trauma. Conventional treatment methods such as prolonged plaster immobilization may lead to complications including secondary fragment displacement, joint stiffness, contractures, and the development of complex regional pain syndrome. Despite advances in surgical techniques, early diagnostic criteria and differentiated treatment approaches for preventing these complications remain insufficiently developed. This study aimed to develop a scientifically based system for comprehensive diagnosis and treatment of distal metaphyseal forearm fractures using minimally invasive techniques combined with instrumental assessment of tissue microcirculation. The research utilized clinical examination together with laser Doppler flowmetry and thermography to analyze microcirculatory dynamics and identify early pathological changes associated with post traumatic complications. The results demonstrated that specific microcirculatory patterns, including deficits in sympathetic regulation, decreased vasoconstrictor response, and redistribution of blood flow toward deeper tissue layers, were early indicators of pathological processes. Thermographic findings such as diffuse hyperthermia of the hand and fingers also provided reliable early diagnostic markers. Implementation of minimally invasive osteosynthesis methods combined with early diagnostic monitoring improved anatomical restoration of the wrist joint and reduced rehabilitation time and disability. The findings suggest that integrating microcirculatory diagnostics with modern fixation techniques can significantly improve treatment outcomes and enable earlier detection and prevention of complex regional pain syndrome in patients with distal forearm fractures.

Keywords: Distal forearm fractures, distal radius fractures, microcirculation, laser Doppler flowmetry, thermography, complex regional pain syndrome, minimally invasive osteosynthesis.

Introduction

Distal forearm fractures represent one of the most common injuries of the musculoskeletal system and account for a significant proportion of upper limb trauma. Fractures of the distal radius are particularly prevalent and frequently occur in middle aged and elderly populations due to bone remodeling, metabolic disorders, and osteoporosis [1]. These injuries often result from low energy trauma and are commonly treated using conservative immobilization methods such as plaster casting. However, prolonged immobilization may lead to complications including joint stiffness, contractures, and the development of complex regional pain syndrome. The physiological basis of these complications is closely related to disturbances in tissue microcirculation and neurovascular regulation during the post traumatic healing period.

Previous studies have examined various surgical and conservative treatment methods for distal radius fractures, with increasing attention to minimally invasive osteosynthesis techniques that allow stable fixation while preserving functional mobility. Nevertheless, many patients are still treated using conventional approaches that do not adequately account for microcirculatory dynamics [2]. Theoretical perspectives in trauma surgery and rehabilitation emphasize the importance of early detection of vascular and neurogenic changes in injured tissues. Despite these advances, there remains a lack of reliable early diagnostic criteria and differentiated treatment strategies that integrate microcirculation assessment into clinical decision making. Existing research also highlights the limited application of instrumental diagnostic techniques such as laser Doppler flowmetry and thermography in identifying early stages of complex regional pain syndrome.

This study aims to address these limitations by conducting a comprehensive analysis of tissue microcirculation dynamics in the uncomplicated post traumatic period of distal forearm fractures. Using clinical examination combined with laser Doppler flowmetry and thermographic assessment, the research evaluates early microvascular changes and their relationship to postoperative outcomes. It is expected that identifying characteristic microcirculatory patterns will enable earlier diagnosis of complications and improve treatment planning [3]. The anticipated findings suggest that integrating minimally invasive osteosynthesis with objective microcirculation monitoring may enhance functional recovery, reduce rehabilitation time, and decrease the incidence of complex regional pain syndrome, thereby contributing to more effective and evidence based management of distal forearm fractures.

Methodology

The study employed a clinical observational design aimed at evaluating the dynamics of tissue microcirculation in patients during the post traumatic period following distal forearm fractures. The research was conducted on patients diagnosed with fractures of the distal metaphysis of the forearm bones who received treatment at a specialized orthopedic unit [4]. Participants were selected based on clinical and radiological confirmation of distal radius or combined forearm fractures, while particular attention was given to patients with varying fracture types and post traumatic conditions. Clinical examination was combined with instrumental diagnostic methods to assess vascular and functional changes during the recovery process.

The primary methodological approach involved the assessment of microcirculatory parameters using laser Doppler flowmetry and infrared thermography. Laser Doppler flowmetry was used to analyze oscillatory blood flow activity, sympathetic vascular regulation, and neurogenic mechanisms affecting microvascular circulation [5]. Spectral analysis of oscillatory rhythms allowed the identification of characteristic patterns related to sensory peptidergic activity and sympathetic adrenergic regulation. In addition, vasoconstrictor respiratory testing was applied to evaluate reflex sympathetic responses in the microvascular system. Thermographic examination was used to detect temperature asymmetry and

localized hyperthermia of the hand and fingers, which served as indicators of inflammatory and vascular changes during the early stages of post traumatic recovery.

Treatment outcomes were assessed through clinical observation of functional recovery, range of motion of the wrist joint, and the presence of complications such as contractures or complex regional pain syndrome. Patients underwent either minimally invasive osteosynthesis techniques or conventional immobilization methods depending on fracture characteristics. Comparative analysis of treatment outcomes, rehabilitation duration, and microcirculatory indicators allowed the evaluation of the effectiveness of the proposed diagnostic and treatment approach and its potential role in improving early detection of complications and optimizing patient recovery [6].

Result and Discussion

Forearm bone fractures account for up to 25% of all musculoskeletal fractures. Fractures of the distal radius metaphysis are the most common upper extremity injuries, accounting for approximately 70-90% of forearm bone fractures. Distal radius fractures are the most common bone injury of the upper extremity. They most often occur in female patients over 40 years of age with minimal trauma, which is undoubtedly associated with physiological remodeling of bone tissue due to metabolic disorders and the development of osteoporosis [7]. In 49-60% of these fractures, they are accompanied by avulsion of the styloid process of the ulna, in 31-58% - by dislocations and subluxations of the ulnar head and damage to the distal radioulnar articulation, and in 2-13% - by fractures of the ulnar head. In winter, especially on icy roads, the number of distal forearm fractures increases sharply.

The diversity of fracture types requires a selective approach to treatment methods and tactics. Despite the fact that in recent years, the vast majority of published papers have focused on various surgical osteosurgery techniques, a wide variety of distal radius fractures are still traditionally treated the same way—with a plaster cast. In the case of comminuted unstable fractures, this is typically complicated by secondary displacement, the development of post-traumatic deformity, tunnel syndromes, and other complications. Unsatisfactory outcomes are particularly common in the elderly, those with concomitant vascular pathology, osteoporosis, and CRPS, the treatment of which is lengthy and labor-intensive, and its diagnosis is difficult, as clear criteria for early diagnosis have not yet been developed [8].

Long-term plaster cast fixation of a fracture leads to stiffness and contractures in the hand joints, requiring long-term conservative treatment, which is often limited due to comorbidities (hypertension, precancerous conditions). There is a lack of differentiated approaches to the use of external and traditional distraction osteosynthesis. Therefore, the aim of our study was to develop a scientifically based system for the comprehensive diagnosis and treatment of patients with distal metaphysis fractures of the forearm bones and their sequelae using minimally invasive techniques that combine stable fixation with freedom of movement in the hand and finger joints [9].

High-amplitude oscillatory activity in the range of 0.05-20.56 Hz, caused by sensory peptidergic mechanisms, was dominant compared to other rhythms. In some cases, blood flow oscillations were synchronized to this rhythm. The red LDF channel exhibited a specific spectral equivalent caused by a deficit in sympathetic adrenergic regulation and an increase in the proportion of sensory peptidergic mechanisms of neurogenic inflammation. Third, patients with CRPS showed a deficit in reflex sympathetic activity during the vasoconstrictor respiratory test starting from the first week after injury. This manifested itself as exhaustion of vasoconstriction during a repeated test at 1-minute intervals (a decrease in the repeated DPM value by 2 or more times compared to the initial value) or a decrease in the DPM value by 50% of the control value. This difference from the normal course of the post-traumatic period was most often observed in the first 2 weeks after injury. Fourth, the early

stages (up to one month post-injury) of CRPS development were characterized by the development of tissue ischemia: not only cardiac rhythm amplitudes (as during normal healing) but also venous respiratory rhythms decreased, indicating further deterioration of venous outflow [10]. This is associated with the development of severe hand edema, especially in stage I CRPS. In general, it should be emphasized that despite the trophotropic direction of microcirculation regulation, the volumetric blood flow in the superficial nutritional microvessels decreased due to the redistribution of blood in favor of deeper layers.

In classic CRPS cases, these symptoms were present simultaneously. However, early after a fracture, some of the above symptoms could be observed even with uncomplicated healing. Therefore, instrumental objective data, allowing for the early diagnosis of CRPS, are particularly important. We have identified these signs for the first time using thermography and LDF. The most reliable early diagnostic criteria for CRPS are LDF parameters (the presence of a spectral vibrational equivalent of hyposympathicotonia and sensory activation, decreased reflex sympathetic vasoconstriction, and an increase in total volumetric blood flow in the deep layers of the skin) and thermography (diffuse hyperthermia of the hand and fingers, hyperthermia of the pad of the 2nd finger $> 0.5^{\circ}\text{C}$) [11].

In patients presenting late with chronic fractures and their sequelae, a risk group was identified based on clinical examination, LDF, and thermography data. These patients had either an insidious clinical picture without instrumental confirmation or instrumental confirmation without clinical symptoms of CRPS. These patients can undergo corrective surgery with minimal soft tissue trauma.

A satisfactory outcome (score from 65 to 69) was defined as a treatment outcome in which anatomical abnormalities were present, to varying degrees limiting limb function, primarily due to pain and contractures in the wrist joint with a limitation of motion of no more than 20 degrees compared to the healthy limb [12]. We also classified the treatment outcomes of patients in the main group as satisfactory if their limb function was restored within a period exceeding 7 weeks. This was the case for 5 (11.63%) patients in the main group. This was due to the fact that 3 of them underwent surgery for a malunion fracture of the distal metaepiphysis of the radius, resulting in deformity and coarcture of the wrist joint. Two patients underwent shortening resection of the distal metadiaphysis of the ulna, corrective osteotomy, and autologous bone grafting of the distal metaepiphysis of the radius using a graft from the resected ulna fragment. In one case, a malunion fracture was treated with corrective osteotomy and autologous bone grafting of the distal metaphysis of the radius using an iliac crest graft. Two patients in the study group underwent closed reduction of fragments and pin-and-rod osteosynthesis for comminuted fractures of the distal portion of both forearm bones. The fixation period for these five patients ranged from 7.5 to 9 weeks.

An unsatisfactory outcome (a score of less than 65) was defined as a treatment outcome in which deformities and contractures significantly impeded upper limb function (wrist range of motion limited by more than 20 degrees) [13][14]. The treatment outcome of one (2.3%) 62-year-old female patient in the study group was considered unsatisfactory. She presented with a comminuted intra-articular fracture of the C3 distal radius metaphysis with signs of secondary fragment displacement and increasing clinical manifestations of CRPS. The surgery was preceded by 3 manual fragment reductions over the first 14 days, followed by plaster immobilization. Despite ideal fragment reduction, minimally invasive surgery, and subsequent early intensive complex therapy, this significantly complicated both the postoperative period and the entire subsequent rehabilitation period. Different outcomes were noted when evaluating the treatment results for patients in the coprolate group. Here, good results with the use of distraction devices with wrist joint fixation were observed in 21 of 32 patients, representing 65.63%. With plaster immobilization, good results were achieved in only 54 of 97 patients, representing 55.67%

of this group. These primarily concerned young and middle-aged patients with type A-51 (52.58%) and B-34 (35.05%) fractures. After the removal of the plaster immobilization, rehabilitation treatment allowed for the restoration of function of the affected limb within 2-3 weeks [15].

Conclusion

Thus, studies have shown that the developed method of osteosynthesis for distal metaepithelial fractures of the forearm bones not only restores the anatomically correct alignment and function of the wrist joint but also significantly reduces the rehabilitation period and patient disability, and reduces the incidence of CRPS. This allows us to recommend this technique for widespread use in medical practice.

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