WEP Warwick Evans Publishing

International Journal of Public Health and Medical Research

ISSN: 3006-7707 (Print), ISSN: 3006-3752 (Online) | Volume 6, Number 1, Year 2026
DOI: https://doi.org/10.62051/ijphmr.v6n1.01
Journal homepage: https://wepub.org/index.php/IJPHMR/index

Staged Integrated Traditional Chinese and Western Medicine Therapy for Complex Open Limb Fractures: Strategy Optimization and Research Progress

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ABSTRACT

Complex open limb fractures represent a significant challenge in the field of trauma orthopedics, characterized by severe bone and soft tissue destruction caused by high-energy injuries, often accompanied by serious complications such as infection, nonunion, and functional impairment. Modern Western medicine treatment follows the damage control concept, establishing a therapeutic system centered on staged surgery, which has significantly improved limb salvage rates. However, limitations remain in controlling local inflammation, promoting tissue regeneration, and functional rehabilitation. Traditional Chinese medicine (TCM) theory emphasizes holistic concepts and syndrome differentiation, with principles such as "simultaneous treatment of bone and soft tissue" and "promoting blood circulation to remove blood stasis" providing unique perspectives for trauma repair. This article systematically explores the organic integration of Chinese and Western medicine treatment methods to form a staged integrated strategy spanning the acute, reconstruction, and rehabilitation phases. During the acute phase, TCM formulas for clearing heat, detoxifying, cooling blood, and resolving stasis can assist in controlling systemic inflammatory responses and creating conditions for surgery. During the reconstruction phase, kidney-tonifying, blood-activating, bone-knitting, and tendon-nourishing Chinese herbs synergize with modern microsurgical techniques to promote synchronous repair of bone and soft tissues. During the rehabilitation phase, TCM fumigation, Daoyin (guided exercise), and manual therapy play a dominant role in functional recovery. By reviewing existing clinical evidence and potential mechanisms of action, this article aims to construct a logical, practical clinical integration pathway to provide theoretical basis and practical references for improving the overall efficacy of complex open fractures, while also outlining key directions for future research.

KEYWORDS

Complex open fractures; Integrated Traditional Chinese and Western Medicine; Staged treatment; Bone repair; Rehabilitation

1. INTRODUCTION

Complex open limb fractures, typically referring to Gustilo type III and above injuries, involve communication between the fracture site and the external environment accompanied by extensive soft tissue damage, severe contamination, or vascular and nerve injuries. Such injuries are mostly caused by high-energy violence such as traffic accidents and falls from height, and their treatment has always been a severe challenge in trauma orthopedics and hand-foot microsurgery. The damage not only causes severe disruption to bone structure but, more critically, delivers devastating blows to the surrounding soft tissue complex including skin, muscle, blood vessels, and nerves, triggering a series

of chain pathological reactions including progressive tissue necrosis, difficult-to-control infection, delayed fracture union or nonunion, and ultimately possibly leading to amputation or severe disability [1, 2].

Modern medicine has developed a relatively mature phased treatment paradigm for this, namely the treatment flow under the concept of Damage Control Orthopedics (DCO). This process emphasizes saving lives and preserving limbs as primary goals during the acute phase, controlling the situation through thorough debridement, temporary external fixation, and anti-infective treatment. After the patient's systemic and local conditions improve, definitive bone fixation and complex soft tissue coverage surgery, such as flap transplantation, are performed in the second stage. Finally, function is restored as much as possible through systematic rehabilitation training. Although this strategy has greatly improved prognosis, clinical practice still faces many bottlenecks, such as the physiological impact of repeated debridement on patients, timing and quality control of soft tissue coverage, prevention and treatment of stubborn complications like osteomyelitis, and rehabilitation challenges of long-term dysfunction [3, 4].

At the same time, Traditional Chinese Medicine (TCM) has accumulated thousands of years of practical experience in treating bone injury diseases, forming a systematic theoretical system. Its core lies in the "holistic view" and "treatment based on syndrome differentiation", believing that trauma leads to "injury of tendons and damage of bones, stagnation of qi and blood", which may subsequently transform into heat and generate toxins, or consume qi, blood, liver, and kidney. In treatment, it not only focuses on "bone setting" but also emphasizes "tendon connecting", "promoting blood circulation", "resolving stasis", and "supporting healthy qi". These principles are highly consistent with the macro goals of modern medicine in promoting healing, controlling infection, and optimizing function, but provide different entry points in terms of intervention methods and action levels [5].

Therefore, exploring the organic combination of Chinese and Western medicine in treating complex open limb fractures is not a simple superposition but seeks precise temporal complementarity and synergistic efficacy enhancement. Integrating the advantages of TCM's overall regulation and syndrome differentiation into the framework of Western medicine's staged surgery is expected to build a more comprehensive and optimized new treatment model. This review aims to systematically explain the theoretical basis, specific implementation pathways, existing scientific evidence of this staged integrated TCM-WM strategy, and analyze its clinical value and future development prospects, in order to provide clear ideas and references for clinical practice and related research.

2. PATHOPHYSIOLOGICAL BASIS AND THERAPEUTIC CHALLENGES

The pathological process of complex open fractures is far from simple bone breakage; its essence is the composite destruction of the "bone-soft tissue functional unit". High-energy trauma instantly causes bone comminution, while shock waves and shear forces lead to extensive tearing, crushing, or even destruction of surrounding muscles, fascia, vascular networks, and nerves. This destruction triggers two core vicious cycles: first, the cycle of blood supply disorder, where main vessel rupture or microcirculatory embolism leads to tissue ischemia, ischemic tissue necrosis becomes a bacterial culture medium, and infection and edema further increase local pressure, worsening blood supply; second, the cycle of excessive inflammation, where tissue damage releases a large number of damage-associated molecular patterns, activating the innate immune system and triggering intense, sometimes uncontrolled local and systemic inflammatory responses. This process, while clearing necrotic material, may also inadvertently damage normal tissue and hinder repair initiation [6, 7].

The resulting clinical challenges are multidimensional. The primary challenge is infection control. Open wounds are contaminated by environmental microorganisms. In an ischemic and necrotic tissue environment, bacteria can easily proliferate in large numbers, leading to acute cellulitis, abscesses, and even refractory osteomyelitis. Second is bone defect and nonunion. Due to periosteal stripping,

bone fragment necrosis, and loss of blood supply, the fracture ends often have segmental defects and lack osteogenic capacity, making it difficult to achieve bony union with conventional fixation. Finally, there is the challenge of functional rehabilitation. Even if the bone is connected and the wound is covered, the functional recovery of damaged nerves, joint stiffness, muscle atrophy, and fibrosis will severely affect the limb's ultimate movement, sensation, and weight-bearing capacity. These challenges are intertwined, making treatment a long and complex process [8, 9].

3. CURRENT STATUS AND FRAMEWORK OF WESTERN MEDICINE STAGED TREATMENT

Currently, the standard Western medicine treatment for complex open limb fractures has formed a staged framework with a clear timeline and treatment goals. The first stage is the emergency treatment phase, with the core being "damage control". Treatment begins within hours of injury, focusing on thorough and potentially repeated debridement surgery to remove all necrotic tissue and foreign bodies, supplemented by extensive pulsed lavage with normal saline. Fractures are typically temporarily stabilized using simple external fixators due to their rapid application and minimal interference with remaining blood supply. At the same time, early and adequate administration of broad-spectrum antibiotics is initiated, often combined with negative pressure wound therapy to manage the wound, aiming to create a relatively clean, edema-reduced local environment for subsequent treatment [10, 11].

The second stage is the reconstruction and repair phase, usually occurring 1 to 3 weeks post-injury, after soft tissue viability boundaries are clear and systemic inflammation has stabilized. The goal of this stage is to achieve permanent bone stability and complete soft tissue coverage. Definitive bone fixation can be selected based on the situation, including intramedullary nailing, plating, or combined fixation, often assisted by microsurgical techniques for vascularized free bone grafting to repair large segmental bone defects. Soft tissue coverage is a critical step in limb salvage, requiring careful design and implementation of local flaps, pedicled flaps, or free flaps based on the location, size, and depth of the defect to provide well-vascularized soft tissue envelope [12, 13].

The third stage is the functional rehabilitation phase, spanning the middle and later stages of treatment. On the basis of solid bone fixation and good soft tissue healing, early initiation of systematic, progressive functional exercise is crucial. This includes joint passive and active movement, muscle strength training, sensory re-education, and gait training under the guidance of rehabilitation therapists, aiming to maximize limb function recovery and prevent complications such as joint contracture and muscle disuse. The entire staged process requires close multidisciplinary collaboration among trauma orthopedics, microsurgery, infectious disease, rehabilitation, and nursing teams [14].

4. THEORETICAL BASIS OF TCM TREATMENT AND STAGED INTEGRATED APPLICATION

TCM's understanding of trauma is based on the "qi and blood" theory. The Yellow Emperor's Inner Classic states: "Qi injury causes pain, form injury causes swelling", believing that trauma causes meridian rupture, blood leaving the vessels becoming "blood stasis", and stasis blocking qi movement is the core pathogenesis of swelling and pain. Therefore, "promoting blood circulation to remove blood stasis" is the fundamental treatment method in the early stage of trauma. Later physicians further proposed the principle of "simultaneous treatment of bone and soft tissue", emphasizing the interdependence of bone and tendons (referring broadly to soft tissue) in physiology, and the necessity of coordinated treatment in order to achieve straightened bones, flexible tendons, and restored function [15, 16].

Based on the above theory, the staged integrated treatment of Chinese and Western medicine can achieve deep integration at different stages. In the acute/emergency phase, corresponding to the Western medicine debridement and temporary fixation stage, the patient's TCM syndrome pattern is mostly identified as "interlocking of stasis and heat, internal accumulation of toxin". In treatment, while performing standardized debridement, early oral administration of Chinese medicine can be given, such as modified "Taohong Siwu Decoction" combined with "Wuwei Xiaodu Decoction", focusing on promoting blood circulation to remove stasis, clearing heat and detoxifying. Modern studies have shown that such formulas can effectively inhibit serum levels of pro-inflammatory factors such as TNF-α and IL-6, reduce systemic inflammatory response, and improve local microcirculation, creating better physiological and local conditions for subsequent surgery [17, 18]. Locally, TCM liquid preparations for clearing heat, detoxifying, drying dampness, and astringing sores can be used for wet compresses or irrigation as appropriate.

Entering the reconstruction/repair phase, corresponding to the Western medicine definitive fixation and flap transplantation stage, the TCM syndrome often transforms into "deficiency of liver and kidney, lingering blood stasis". At this time, the treatment focus shifts to "bone-knitting, tendon-nourishing, tonifying liver and kidney". Postoperatively, formulas such as "Jiegu Qili Tablet" or self-prescribed "Bushen Huoxue Jiegu Decoction" can be used in combination. Pharmacological research suggests that active ingredients in commonly used herbs in such formulas, such as Drynaria fortunei, Dipsacus asperoides, and Epimedium brevicornum, can promote osteoblast proliferation and differentiation, accelerate calcium salt deposition, and enhance the speed and strength of fracture healing [19, 20]. At the same time, supplementing with qi-tonifying and blood-nourishing herbs helps improve flap survival rate and promote soft tissue healing. At this stage, acupuncture can also be combined, selecting points such as Zusanli (ST36), Hegu (LI4), and Ashi points, to achieve effects such as auxiliary analgesia, reducing postoperative nausea and vomiting, and promoting gastrointestinal function recovery [21].

In the functional rehabilitation phase, where the treatment goal is to maximize functional recovery, TCM methods can play a dominant role. First is herbal fumigation and washing. Herbs with effects of warming meridians, unblocking collaterals, relaxing tendons, and activating blood, such as Erythrina variegata, Gnetum parvifolium, Speranskia tuberculata, and Cinnamomum cassia, are decocted and used for steaming and soaking the affected limb joints while hot. This can effectively relieve joint stiffness, soft tissue adhesion, and chronic swelling and pain [22]. Second is TCM Daoyin and manual therapy. Based on the injured site, patients are guided in specific, progressive functional exercises for joint flexion, extension, rotation, etc. (Daoyin), combined with gentle Tuina massage techniques to release contracted tendons and scar tissue and promote qi and blood flow. Third is continuous oral conditioning. For common patterns in the later stage of fracture such as "deficiency of both qi and blood" or "deficiency of liver and kidney", formulas like Bazhen Decoction or Zuogui Pill with modifications are given to consolidate efficacy, strengthen constitution, and promote comprehensive recovery [23].

5. CLINICAL EVIDENCE AND DISCUSSION OF MECHANISMS

In recent years, an increasing number of clinical studies have provided supporting evidence for the integrated Chinese and Western medicine treatment of complex fractures. Multiple clinical observations and controlled trials have shown that combining TCM with standard Western medicine treatment can significantly reduce wound infection rates and osteomyelitis incidence in patients with Gustilo type III fractures, shorten clinical fracture healing time, and demonstrate advantages in final functional scores (such as ankle-hindfoot score, knee HSS score). For example, a randomized controlled study on open tibiofibular fractures showed that the integrated Chinese and Western medicine group had significantly better infection control rates and excellent/good rates of fracture healing at 6 months postoperatively compared to the Western medicine-only treatment group [24].

At the level of mechanism exploration, modern pharmacological research is gradually revealing the scientific connotation of some Chinese herbs and their compounds. In terms of anti-inflammatory and immunomodulation, alkaloids and anthraquinones in heat-clearing and detoxifying herbs such as Coptis chinensis and Rheum palmatum have been confirmed to inhibit the over-activation of key inflammatory signaling pathways such as NF-κB. In promoting angiogenesis, active ingredients in blood-activating and stasis-resolving herbs such as Salvia miltiorrhiza and Ligusticum chuanxiong can upregulate the expression of vascular endothelial growth factor, stimulating the formation of new capillary networks in the injured area. In promoting osteogenesis and chondrogenesis, compounds derived from kidney-tonifying and bone-strengthening herbs such as icariin and naringin can activate classic osteogenic differentiation pathways like bone morphogenetic protein and Wnt/β-catenin, promote the directional differentiation of mesenchymal stem cells into the osteoblast lineage, and inhibit osteoclast activity. These multi-target, multi-pathway regulatory effects form a beneficial complement to Western medicine treatment [25, 26].

6. INTEGRATION STRATEGY OPTIMIZATION AND CLINICAL PATHWAY CONSTRUCTION

To achieve standardization and optimization of the integration of Chinese and Western medicine, constructing a clear clinical decision pathway is crucial. The ideal integration pathway should be patient-centered, using the timeline as a clue, and clarifying the respective roles and collaboration points of Chinese and Western medicine at each stage. It is recommended to establish a fixed multidisciplinary team in large trauma centers, including experts in trauma orthopedics, hand-foot microsurgery, TCM orthopedics, rehabilitation medicine, and clinical pharmacy. For each patient with complex open fracture, the team should conduct a joint assessment early after admission and develop a personalized integrated plan spanning the entire treatment cycle [27].

In the acute phase, the treatment plan is led by trauma orthopedics and microsurgery, with TCM physicians participating in syndrome differentiation, providing suggestions for oral and external Chinese medicine, collaborating to control inflammation and stabilize the internal environment. During the reconstruction phase, the surgical team executes the plan while TCM practitioners provide synchronous treatment. This complementary therapy focuses on auxiliary analgesia and promoting the healing of bone and soft tissue. Additionally, pharmacy experts must monitor potential drug interactions. During the long rehabilitation phase, the leading role in treatment can shift towards rehabilitation and TCM orthopedics, with the surgical team responsible for regularly assessing bone healing and implant status. Throughout the process, a shared medical record system and regular team discussion system should be established to dynamically adjust the treatment plan based on the patient's recovery [28].

Currently, challenges in promoting this integrated model include: lack of national or industry consensus guidelines; the degree of standardization of TCM syndrome differentiation and intervention measures needs improvement; and more rigorously designed high-level evidence-based medical evidence is needed to support its widespread promotion. Future research should focus on conducting large-scale, multi-center, prospective randomized controlled trials, and utilize systems biology methods such as metabolomics and proteomics to deeply elucidate the network biological mechanisms of the synergistic effects of Chinese and Western medicine integration, ultimately promoting the formation of evidence-based, standardized, and effective diagnosis and treatment guidelines for the integrated Chinese and Western medicine treatment of complex open limb fractures [29].

7. CONCLUSION AND PROSPECTS

The treatment of complex open limb fractures is a systematic project. Relying solely on Western medicine staged surgical techniques, while able to solve most structural reconstruction problems, has inherent boundaries in regulating the repair microenvironment, promoting tissue regeneration, and functional rehabilitation. Traditional Chinese Medicine, with its unique advantages of overall regulation and treatment based on syndrome differentiation, can provide effective supplementation at these levels. The staged integrated TCM-WM strategy elaborated in this article emphasizes the organic and chronological integration of the core technologies of the two medical systems according to the main contradictions at different stages of the disease, with the goal of achieving a leap from "anatomical reduction" to "functional reduction".

This model represents the trend of modern trauma treatment towards integrative medicine. It requires clinicians not only to be proficient in their own specialty techniques but also to possess interdisciplinary understanding and cooperation abilities. Looking forward, through continuous deepening of clinical and basic research, establishing standardized integration pathways, and strengthening the training of complex talents, the integration of Chinese and Western medicine is expected to provide a "Chinese solution" that is more resilient, more humanistic, and more effective for the global challenge of complex open limb fractures, ultimately benefiting more patients and enabling them to return to healthy lives.

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