Fasciotomy through Multiple Small Skin Incisions for the treatment of early acute osteofascial compartment syndrome in children

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Abstract

Background

Surgical decompression should be applied at the earliest stage of osteofascial compartment syndrome. Traditional fasciotomy was useful to decompress the compartment pressure, but may lead to serious complications and requirement of a second operation to close the wound. The purpose of the present study is to investigate the therapeutic effect of fasciotomy through multiple small skin incisions for the treatment of early osteofascial compartment syndrome in children.

Methods

From January 2009 to May 2017, 56 pediatric patients with early osteofascial compartment syndrome in their limbs were admitted into our department and treated with multiple small skin incisions for decompression at the early stage. The skin incisions, function and sensation of the limbs were followed up.

Results

The OCS was diagnosed at 7.4±2.1 hours after injury, and then fasciotomy was performed at 1.4±0.4 hours later. The average procedure time of fasciotomy was 12.7±4.8 minutes. No postoperative incision infections or neurovascular injuries were observed in all the patients. The incisions completely healed in 7-10 days with an average healing time of 8 days without secondary suture. The patients were followed up for an average of 5.1 years. No Volkmann’s contractures in the injured limbs were found. The appearance, electromyography and nerve conduction velocity of the affected limbs were not significantly different from that of the contralateral limbs. All the patients were free of symptoms, were full recovery of sensation and function, being an “excellent” outcome at the latest follow-up.
Conclusion

Fasciotomy through multiple small skin incisions, which can be useful to decompress the compartment pressure with fewer complications, is a simple and effective strategy for the treatment of early osteofascial compartment syndrome in children.

Introduction

Osteofascial compartment syndrome (OCS) is one of the serious emergency conditions in pediatric orthopedics that is often accompanied by extremity fractures, vascular injuries, soft tissue crush injuries caused by car accidents or earthquakes, and improper external fixation. [1, 2] It is a progressive acute illness that can lead to total or partial loss of limb sensorimotor functions or even severe organ failure if it is not diagnosed and treated in time. Therefore, it is critical to diagnose and treat this disease at its earliest stage. [3, 4]

Surgical decompression is the only effective treatment of this disease if conservative treatment fails. [1-3] Traditional method of decompression was fasciotomy through a large incision, which immediately reduced the compartment pressure to minimize ongoing tissue damage and long-term functional deficit of the myoneural tissues within the compartment, being the standard treatment for OCS. However, there were neurovascular injury, scar, operation trauma, superficial or deep wound infections, and other serious complications in the traditional fasciotomy. 12-21% of cases require a second operation such as skin grafting or tissue expansion to close the wound. [5, 6] Since these serious complications, the traditional fasciotomy is applied scrupulously in the early OCS, especially in the doubtful cases, missing the best time for treatment, leading to neuromusrosis and
subsequent poor outcomes.

Development of a fasciotomy through little wound is of great value in the early OCS. In 1993, DiStasio AJ 2nd et al used multiple relaxing skin incisions to facilitate the closure of difficult lower extremity wounds when they noted extreme tension (skin blanching, gapping) caused by swelling or soft tissue loss. There was no requirement of soft tissue coverage procedures, and no serious complications such as delayed wound healing, superficial or deep wound infections, and compartment syndrome. The results confirmed that the use multiple relaxing skin incisions was a safe, simple and realizable technique for closure of complicated swelling wound. [7]

Relaxation incisions were performed to treat compartment syndrome caused by snake bite injury. [8, 9] Akira S et al found that relaxation incisions could be useful not only to wash out the venom from the bitten region but also to decompress subcutaneous and compartment pressure of the hand bit by venomous snake “Japanese mamushi”. [10]

From January 2009 to May 2017, 56 pediatric patients with early OCS in the extremities were admitted to our department and treated with multiple small skin incisions for decompression. These patients were followed up for an average period of 5.6 years, their records were analyzed to evaluate the clinical effects of fasciotomy through multiple small skin incisions for the treatment of early OCS in children.

Methods

Patients

This study was approved and supervised by the Ethics Committee of the Children’s
Hospital of Chongqing Medical University and was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. The early osteofascial compartment syndrome (OCS) was diagnosed and evaluated by two experienced surgeons according to signs and symptoms of the patients. [2-4] Exclusion criteria were patients older than 18 years, with neurovascular injury of the limbs, and incomplete medical records. From January 2009 to May 2017, 56 pediatric patients with early OCS were involved in this study, and their records such as demographic profiles, injury mechanisms, cause of OCS, and hospitalization information were retrieved and analyzed retrospectively.

Surgical procedure

Once the patient was suspected to suffer from OCS, the external fixation was removed immediately, and the affected limb was raised to relieve swelling. Mannitol (20%) was injected intravenously at 5 ml/kg and repeated once after 2 hours. If no improvement was observed after 2-4 hours, local reticular incisions were immediately performed on the affected limb for decompression after satisfactory general anesthetization and disinfection. Skin incisions were made from 0.5-1.0 cm using sharp blades. Subcutaneous and deep fascias were separated to intermuscular septa using a vascular clamp until exudates were observed. Muscle bulges were even observed in some cases. Multiple small incisions were made every 0.5-1.0 cm for decompression in the area with obvious swelling and high tension (Figure 1). To avoid injuries to the blood vessels and nerves, closed reduction and Orthofix external fixation were performed in the patients with radial and ulnar shaft fractures or tibial and fibular shaft fractures. The reduction and fixation of all other fractures were performed during the second phase of treatment. The wound surface
was covered with gauze after the surgery, and the affected limb was laid flat. Dehydration with 20% mannitol and proper use of antibiotics were employed to prevent infection in the incision. The incision dressing was changed regularly. Routine bacterial cultures were performed once or twice at 3 and 7 days after the surgery before the incision healed. Drug sensitivity tests were performed to adjust the antibiotics used.

Follow-up

The skin incisions, function and sensation of the limbs were followed up. The clinical outcome at the time of the latest follow-up was recorded and graded as ‘‘excellent’’ (free of symptoms, no loss of sensation or function), ‘‘fair’’ (major recovery of sensation and function, the need for a minor assistive device), or ‘‘poor’’ (major loss of sensation or function, the need for a major assistive device). [11,12] At the last follow-up, electromyography and nerve conduction velocity were used to evaluate the neuromuscular function of the affected limbs.

Results

The demographic profiles of the patients were shown in Table 1. From January 2009 to May 2017, a total of 56 pediatric patients with early osteofascial compartment syndrome (OCS), 39 males and 17 females aged between 1.2 and 13.8 years old with an average of 6.5 years old, were treated with reticular incisions in our department. Among these patients, 14 cases showed the condition in the forearm, 29 cases in the lower leg, 5 cases in the hand, and 8 cases in the foot. Thirty-two cases were caused by crush injuries from car accidents, ten cases by injuries from dropped heavy objects, and fourteen cases by improper fracture treatment or overtight plaster casts or splints. 51 of the 56 patients were associated with
fractures in the injured limbs, including humeral supracondylar fractures, radius and ulna fractures, metacarpal fractures, tibia and fibula fractures, and foot fractures, which were all closed fractures without open wounds. When admitted into the hospital, the patients exhibited marked swelling and increasing pain in the affected limb, 37 of them (66.1%) with apparent passive stretching pain, 25 (44.6%) with tension blisters, 11 (19.6%) with weak arterial pulsation, 18 (32.1%) with cold extremities, and 16 (28.6%) with numbness.

Table 1
The demographic profiles of the 56 patients with early osteofascial compartment syndrome

| Sex           | Male (n) | Female (n) |
|---------------|----------|------------|
| Age (years)   | 6.5 (1.2–13.8) |
| Injury mechanism | Traffic accidents (n) | 32 |
|                | Crushing (n) | 10 |
|                | Improper external fixation (n) | 14 |
| Accompanying fracture (n = 51) | Humeral supracondylar fracture (n) | 15 |
|                | Radius and ulna fracture (n) | 11 |
|                | Metacarpal fracture (n) | 9 |
|                | Tibia and fibula fracture (n) | 10 |
|                | Foot fracture (n) | 6 |

The OCS was diagnosed at 7.4 ± 2.1 hours after injury, and then fasciotomy was performed at 1.4 ± 0.4 hours later, that was 8.5 ± 2.4 hours after injury. The fasciotomy was performed in a second surgical procedure after fracture reduction in 40 of the 51 cases, and in the same procedure as the fracture treatment in the other 11 cases. All the fasciotomy was performed through reticular incisions. The average procedure time of fasciotomy (from multiple incisions started to decompression completed) was 12.7 ± 4.8 minutes, and the amount of bleeding was 18.7 ± 4.1 mL.

No postoperative incision infections or neurovascular injuries were observed in all the patients. No bacterial growth was observed in the bacterial cultures. The incisions completely healed in 7–10 days with an average healing time of 8 days.
without secondary suture. No patients required a secondary surgery for
decompression through traditional fasciotomy via a large incision. No osteomyelitis
or bone delayed union were found in the patients. The mean hospital stay was 8.3
days (range from 7 to 10 days).
The patients were followed up for 1-8.5 years after surgery with an average of
5.1 years. No Volkmann’s contractures in the injured limbs were found. The
appearance, electromyography and nerve conduction velocity of the affected limbs
were not significantly different from that of the contralateral limbs. All the patients
were free of symptoms, were full recovery of sensation and function, being an
“excellent” outcome at the latest follow-up. There was a total satisfactory rate of
98.2%. A typical case is shown in Fig. 2.

Discussion
Osteofascial compartment syndrome (OCS) is a serious emergency condition in
pediatric orthopedics. If not treated properly, it is liable to lead to ischemic muscle
contracture (Volkmann’s contracture) with a high rate of disability. OCS not only
affects the body functions but also significantly influences the psychological health
of the pediatric patients. [1-4] Due to impacts from heavy objects, crush injuries or
long-term compression (overtight or prolonged fixation by small splints or plaster
casts), the removal of the pressure causes blood reperfusion and results in the
bleeding and reactive swelling of injured tissues (mainly muscular tissues), which
leads to the increased volume of contents in intermuscular septa followed by
increased pressures and acute OCS. Acute OCS can cause rhabdomyolysis and acute
muscular atrophy, disseminated intravascular coagulation, electrolyte disturbance,
renal failure, and other complications and even death in some severe cases.
The typical symptoms and physical signs of OCS can usually be described clinically as the "5P" symptoms: namely, Pain or from pain to painless, pallor, pulselessness, paralysis, and paresthesia. However, when the injured limbs show the typical "5P" symptoms, the best time for treatment has often been missed, which may result in serious consequences such as physical disability and even amputations.\[13\] Severe pain not consistent with the degree of injuries, passive stretching pains in the limbs, as well as sensory loss within the region where the injured nerves are distributed have long been considered as important clinical signs indicating OCS. In the present study, OCS was diagnosed based on the presence of evident post-traumatic swelling and pain, especially passive stretching pain. In other clinical retrospective studies, it has been found that 100% of the subjects suffered passive stretching pains in the limbs and 60% experienced paresthesia.\[14\] OCS can be diagnosed if the osteofascial compartment pressure is higher than 30 mmHg in the patients with a history of trauma and a high degree of local swelling in the limbs.\[13, 15\] However, pediatric patients often have poor descriptive capability, do not cooperate during physical examination, and cannot accurately express their sensation. In addition, pressure measuring devices are not equipped in the hospitals in underdeveloped areas, and pressure measurement is inaccurate in some cases, leading to limited application of pressure measure in the diagnosis of OCS.\[16\] Therefore, health care providers should carefully observe the conditions of the patients and be vigilant for the occurrence of this disease.\[3, 13, 17\] Even though conservative treatments, such as mannitol, can be applied for this disease at an early stage, the only timely and effective treatment for this disease is effective decompression therapy prior to the aggravation of the condition when the
ischemic changes in the muscular tissues are still reversible. [1-3] Currently, the complete incision for osteofascial compartment decompression at an early stage is the only way to effectively prevent ischemic necrosis of the muscles and nerves. Incision decompression should be performed immediately once the diagnosis is confirmed and short-term conservative treatments are not effective. Early incision is preferred when compared with delayed treatment. [18, 19] The gold standards for the treatment of OCS are early diagnosis and emergent surgical decompression through fasciotomy within 8 hours. Therefore, the treatment for OCS is focused on early decompression but is not unlimited conservative treatment only. [20, 21] In the present study, incision decompression was immediately performed for all the patients who did not show improvement 2–4 hours after conservative therapy, which produced significant therapeutic effects.

The choice of surgical incision size has been controversial. Large incisions are traditionally considered to be more conducive to the removal of necrotic tissue and complete decompression. However, large incisions are prone to complications of infection and prolonged periods of dressing changes. Moreover, second-phase wound sutures, even dermoplasty, are required for wound healing, which leaves visible scars that affect the patient’s appearance. [5-6] Thus, we prefer multiple small incisions for decompression. Incision decompression was performed in the areas with marked swelling and elevated tension, which on one hand provides complete and effective decompression and on the other hand allows for closed reduction and external fixation of fractures and avoids secondary surgeries. In the present study, the results suggested that fasciotomy via multiple small skin incisions was simple and fast operation procedure with less trauma, shorter
operation time, without space restrictions, and was suitable for emergency
treatment and surgeries in remote mountainous areas and field sites. Moreover,
multiple small skin incisions are associated with less intraoperative blood loss, good
postoperative recovery of local skin, little impact on the appearance, easier second-
phase wound healing, and low infection rate.
However, small incision has its limitations. The multiple small skin incisions can only
provide timely and effective decompression for osteofascial compartment, but
cannot completely clear the ischemic necrotic tissues and repair the injured blood
vessels or nerves. Therefore, fasciotomy via multiple small skin incisions is only
recommended for early OCS without neurovascular injury.

Conclusion
Acute osteofascial compartment syndrome is a serious emergency condition in
pediatric orthopedics which require an immediate fasciotomy to reduce the
compartment pressure to minimize ongoing tissue damage and long-term functional
deficit of the myoneural tissues within the compartment. The present study shows
fasciotomy through multiple small skin incisions, which can be useful to decompress
the compartment pressure with fewer complications, is a simple and effective
strategy for the treatment of early acute osteofascial compartment syndrome in
children.

List of abbreviations
OCS: osteofascial compartment syndrome

Declarations
**Ethical approval and consent to participate**

This study was approved and supervised by the ethics committee of the Children’s Hospital of Chongqing Medical University and was performed in accordance with the ethical standards of the 1964 Declaration of Helsinki. Informed written consent was obtained from all patients.

**Consent for publication**

The subject shown in Figure 2 and her parents provided their written informed consent for publication of the images.

**Availability of data and materials**

The datasets analysed in the study are available from the corresponding author on reasonable request.

**Competing interests**

The authors declare that they have no competing interests.

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**Authors’ contributions**

Xing Liu and Jun Wu designed the study. Xing Liu and Xiaowei Yuan selected the appropriate patients and included them in this study. Xiaowei Yuan, Xiangyang Qu, Ming Li and Linjun Jiang collected the data and performed the statistical analysis. Jun Wu drafted the manuscript. Jun Wu, Xing Liu and Xiaowei Yuan critically revised the manuscript. All authors have read and approved the final manuscript.

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Figures

![Figure 1](image_url)

*Figure 1*

The operation diagram.
Figure 2

A 5 years-old girl presented to our department with a painful, swollen right hand.