CASE REPORT

Interrupted Incision Fasciotomy for Acute Compartment Syndrome After Extracorporeal Membrane Oxygenation: Surgical Technique with a Report of Two Cases

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Background: After extracorporeal membrane oxygenation (ECMO), acute compartment syndrome (ACS) can develop because of limb ischemia or reperfusion. The standard treatment for ACS is emergency fasciotomy. We introduced an interrupted incision technique instead of a long double-incision to reduce blood loss and subsequent hypovolemia in ECMO patients.

Case presentation: Two patients were treated venoarterial ECMO with heparinization by inserting cannulas into their right femoral vessels: Case #1 after emergency pulmonary thrombectomy for massive pulmonary thrombi and Case #2 after percutaneous coronary intervention for ST-elevation myocardial infarction with ventricular fibrillation. Some of the '5 P' signs of ACS were detected on their right legs. We treated them with the interrupted incision fasciotomy: four or five skin incisions of 2–3 cm each on lateral side; one 6–7 cm proximal skin incision with one or two separate short distal skin incisions of 1–1.5 cm each on the posteromedial side. The subcutaneous layer was also incised through these interrupted incisions; interrupted multiple "soft tissue tunnels" can be formed above muscle layer between the incisions. Once the fascia was exposed, the connected fasciotomy was performed with the knife blade facing subcutaneous layer, rather than muscle. The two patients' foot pulse, skin color, and muscle tone were immediately restored, and delayed primary wound closures were possible. Both patients were satisfied with their limb salvage and could walk with a little help using an orthosis or a cane.

Conclusions: We recommend the interrupted incision fasciotomy as an attractive and effective technique for ACS, particularly after ECMO.

Key words: Acute compartment syndrome; Extracorporeal membrane oxygenation; Fasciotomy; Interrupted incision; Long double-incision

Introduction

Acute compartment syndrome (ACS) is a surgical emergency in which increased compartment pressure within an enclosed space impairs the viability of tissues such as the muscles, nerves, and blood vessels[1]. Extracorporeal membrane oxygenation (ECMO) is a promising option for cardiopulmonary resuscitation. Although severe musculoskeletal or neurovascular trauma is the most common cause of ACS[2], ECMO can also cause ACS due to limb ischemia or reperfusion injury[3,4]. If in doubt about ACS, missing clinical signs can threaten the limbs; hence, an emergency fasciotomy should be performed. Patients with ECMO are prone to excessive bleeding because of ECMO-related anticoagulation.

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Therefore, it is difficult to manage limb ACS during ECMO, and infection or necrosis can lead to limb amputation[4]. The conventional long double-incision fasciotomy for the treatment of ACS can result in abrupt excessive bleeding in the skin, subcutaneous tissue, fascia, and even muscles, due to a single deep incision usually performed in emergency situations. In vulnerable ECMO patients, persistent bleeding from an open fascia wound can cause hypovolemia and can be life-threatening. We describe an effective surgical technique of interrupted incision fasciotomy and present acceptable surgical outcomes in two patients who developed ACS after starting ECMO. The study was exempted from the institutional review board review owing to its retrospective case report design. Informed consent was obtained from both patients for publication of this report and accompanying images.

Surgical Technique

The patient is in a supine position under general anesthesia. Then, four or five skin incisions of 2–3 cm each are made on the lateral aspect of the limb, and one 6–7 cm proximal skin incision is made with one or two separate short distal skin incisions of 1–1.5 cm each on the posteromedial aspect of the limb (Fig. 1). A longer incision was used on the posteromedial compartment than on the lateral compartment to compensate for insufficient decompression of the deep posterior compartment. The subcutaneous layer is also incised through these interrupted incisions in the same fashion; then, interrupted multiple "soft tissue tunnels" can be formed above the muscle layer between the incisions. Once the fascia is exposed, the connected fasciotomy is performed

Fig. 1 (A) Four short incisions performed over the lateral compartment, and (B) one relatively long proximal incision together with two very short distal incisions over the posteromedial compartment.

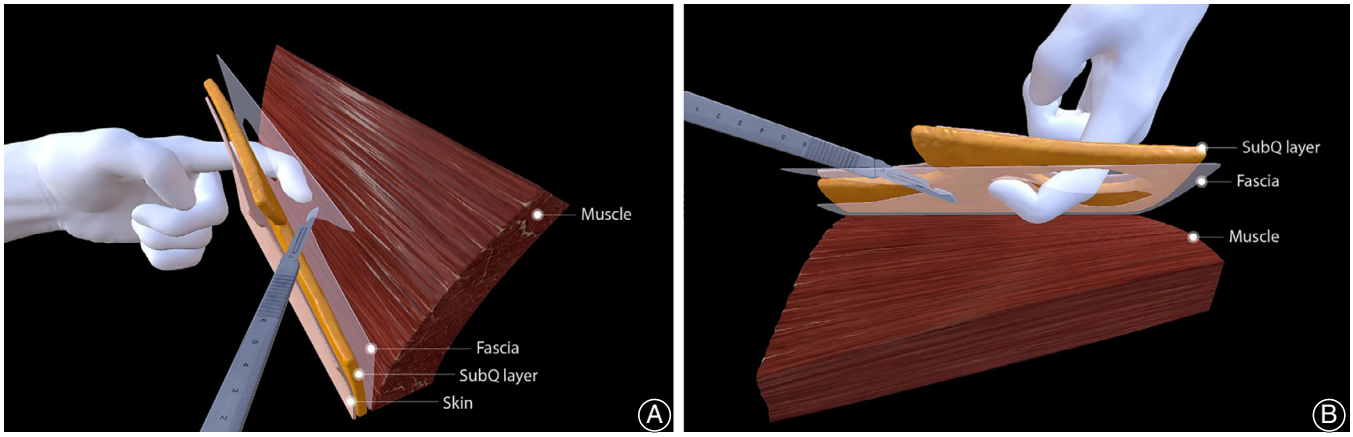

Fig. 2 Illustration of the interrupted incision fasciotomy technique. (A) The knife blade facing toward the subcutaneous layer, not toward the muscle. (B) The surgeon's index finger, inserted into the interrupted incision, pulls the skin and subcutaneous "tunnel" from the muscle. This technique ensures the safe and effective connected fasciotomy underneath the skin and subcutaneous flap "tunnel."

with the knife blade facing the subcutaneous layer, rather than the muscle (Fig. 2A). At this point, the surgeon inserts his/her index finger (including, or not, the middle finger) of the non-dominant hand into the interrupted incision and pulls the skin and subcutaneous "tunnel" from the muscle (Fig. 2B). This technique is beneficial for invisibly connected fasciotomy and does not induce damage to the skin, subcutaneous, and muscle layers. In addition, it is a safe technique to protect the neurovascular structures. After fasciotomy, daily sterile wet to dry dressings are maintained and should be changed if blood oozing through gauze is visible.

Case Report

Case #1

A 50-year-old woman with major depressive disorder visited the emergency room after a seizure episode. Echocardiography showed dysfunctional dilated right atrium and ventricle. Massive pulmonary thrombi were detected. Following an emergency pulmonary thrombectomy, the venoarterial (VA) ECMO with heparinization was started by inserting cannulas into her right femoral vessels. On day 3, weak pulses, multiple blisters, and skin discoloration were observed on her right limb. An emergency fasciotomy was required at the bedside in the intensive care unit without additional anesthesia as she was already in an unconscious state due to the use of sedatives. Interrupted incision fasciotomy was performed in the lateral and posteromedial compartment (Fig. 3). After 2 days, the foot pulse and skin color were restored, and after 7 days, a delayed primary wound closure was performed. We did not perform additional wound management such as skin graft or flap surgery. Her right limb was salvaged from necrosis and amputation. At the 3.5-year follow-up, she was satisfied with her limb salvage despite the foot drop sequelae and was able to walk by herself using an ankle-foot orthosis brace (Fig. 4A).

Fig. 3 A 50-year-old woman who underwent an emergency pulmonary thrombectomy due to massive pulmonary thrombi. On the third day of ECMO, her right limb became swollen and discolored, and the pulse disappeared. (A) Interrupted incision fasciotomy for the lateral compartment. (B) Since it was our first trial of this technique, we used two separate mid-length interrupted incisions for the posteromedial fasciotomy.

Case #2

A 67-year-old man with sudden chest pain was transferred to the emergency department. He had an ST-elevation myocardial infarction with ventricular fibrillation. Emergency coronary angiography was performed with percutaneous coronary intervention and VA ECMO was initiated. Two days later, his right limb was swollen and paralyzed and the pulse disappeared. The measured intracompartmental pressure (ICP) elevated to 80 mmHg in the anterior compartment. The foot pulse, skin color, and muscle tone were immediately restored after interrupted incision fasciotomy. The ICP was also reduced to 17 mmHg in the anterior compartment. Delayed primary wound closure was possible after negative pressure wound therapy on day 8 following fasciotomy. At the 2-year follow-up, he showed improved muscle strength and could walk by himself using a cane (Fig. 4B). His ankle and great toe dorsiflexion strength had restored to grade 4.

Discussion

ACS is an emergency condition threatening limbs with fatal sequelae. Delayed diagnosis or improper treatment of ACS can lead to tissue necrosis, ischemic contracture, neurologic deficits, infection, amputation, or even death[2]. The cardinal signs of ACS are the 5 Ps: pain, pallor, paresthesia, paralysis, and pulselessness. Pain is a major clinical symptom of ACS[5]. Lack of pulse is a late sign of ACS[6]. In unconscious patients, it is difficult to detect ACS because pain, paresthesia, and paralysis cannot be verbalized. ICP measurement as an adjunctive diagnostic technique in doubtful cases can be helpful; however, the diagnostic effectiveness is controversial[7], and there is no agreement on the pressure level above which fasciotomy should be performed[8]. Moreover, there is often not enough time to measure the pressure in emergency situations. A high index of suspicion is crucial for early detection and decompression[9].

There are several iatrogenic causes of ACS, such as tight casting, prolonged tourniquet application, intravenous fluid extravasation, and pelvic surgery. ECMO has also been reported as a cause of ACS[3,4]. During ECMO, the femoral arterial cannulation fits tightly in the femoral artery and occludes the distal arterial lumen, causing distal limb ischemia[10]. Recently, cannula size has been identified as a factor in the development of ischemic complications following ECMO[11]. As another technique to prevent limb ischemia and ACS, prophylactic insertion of a distal perfusion catheter should be considered at the start of ECMO[12].

Fig. 4 Two patients with ACS following ECMO were treated well with interrupted incision fasciotomy. (A) The right limb of a 50-year-old woman who underwent a pulmonary thrombectomy (Case #1) at the 3.5-year follow-up. (B) The right limb of a 67-year-old man who underwent an emergency coronary intervention (Case #2) at the 2-year follow-up. Both patients were satisfied with their limb salvage and could walk alone with a little help using an orthosis or a cane.

The standard treatment for ACS is immediate fasciotomy. The long double-incision, four-compartment fasciotomy is a conventional and standard technique[7,13]. Although it provides good visualization of the anatomical structure and allows decompression of all compartments[13], we believe that long double incisions could induce excessive bleeding through open wounds until closed. The decompressed muscle compartments should be exposed for several days or weeks, and the sterile dressing should be changed daily. In the case of massive muscle bleeding, the dressing should be changed more frequently. Continuous blood oozing from long, wide wounds with each dressing change can be a problem, especially for vulnerable ECMO patients. The persistent blood loss can lead to hypovolemia, which in turn means a "pre-load" problem in the patient's heart. The wounds being exposed for a certain period of time increases the risk of infection and delays wound healing[14]. A previous study of patients after vascular surgery reported 11% mortality and 21% amputation rates[8]. Heemskerk and Kitslaar[15] reported 36% mortality and 18% amputation rates even after a fasciotomy.

Several types of minimal incision fasciotomy have been reported for compartment syndrome[14,16–20]. However, most previous studies have considered cadaver models[18,19], traumatic ACS in children[20], or chronic exertional compartment syndrome[14,17]. There are still very few clinical reports describing fasciotomy techniques for ACS, especially after ECMO. Prior to these two cases, we performed a conventional long double-incision fasciotomy for ACS during ECMO and experienced adverse outcomes such as uncontrolled bleeding, infection, necrosis, difficult wound closure, repetitive skin grafts, amputation, and death. We believed that ECMO patients are particularly vulnerable to excessive bleeding; hence, the interrupted incision fasciotomy technique may be useful to minimize blood loss. In addition, the skin and subcutaneous flap "tunnels" between the interrupted incisions protect the exposed muscles, acting as a soft tissue envelope and a barrier against infection. Interrupted incisions are easier to close than long double incisions and do not require reconstructive surgery such as skin graft or flap coverage. The interrupted incision fasciotomy is easy to perform and is a reproducible surgical technique.

Conclusion

The interrupted incision fasciotomy technique for ACS is an attractive and effective technique that can replace the conventional long double-incision fasciotomy for limb salvage, particularly in ECMO patients.

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