우측 전완부와 수부에 화상과 압제손상을 입은 환자에서 즉시 근막절제술: 증례보고

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Immediate Fasciotomy for Acute Thermal Contact Burn Combined with Compression Injury of the Right Forearm and Hand: A Case Report

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Treatment of compartment syndrome is early decompressive fasciotomy to prevent dreadful sequelae of ischemic necrosis of muscles and nerves. We experienced one patient of impending or early compartment syndrome of right forearm and hand caused by a hot compress machine. We did immediate fasciotomy on forearm and late flap coverage with skin graft in this patient with good results. (*J Korean Burn Soc* 2020;23:13-19)

Key Words: Contact burn, Compression injury, Compartment syndrome, Immediate fasciotomy

INTRODUCTION

Compartment syndrome is caused by increased compartmental pressure usually caused by trauma. Increased compartmental pressure causes arteriovenous (AV) gradient decreases, resulting in decreased local blood flow (LBF). A decrease of LBF causes ischemia, cellular damage, cell lysis¹⁾, and finally Volkmann's ischemic contracture (VIC). Volkmann's ischemic contracture is a serious complication of ischemic necrosis of the muscles and nerves²⁾. It is significantly difficult or impossible to restore the function of the muscles and nerves after VIC³⁾. Therefore, early diagnosis of compartment syndrome is important, and early decompression is necessary.

The treatment of compartment syndrome is early de-

compression to reduce the increased compartmental pressure. Early decompression is achieved via fasciotomy. However, fasciotomy is not a simple procedure, usually requiring later coverage with a skin graft or flap surgery. Therefore, accurate diagnosis of compartment syndrome is important to avoid unnecessary fasciotomy.

Generally compartment syndrome is diagnosed based on clinical symptoms and signs. The symptoms of compartment syndrome are known as the 5 Ps: pain, pallor, paresthesia, paralysis, and pulselessness. If an objective pressure examination revealed elevated intracompartmental pressure, compartment syndrome could be diagnosed more accurately³⁾. However, a standard diagnostic tool used to treat compartment syndrome is not yet available. Therefore, the presence of all 5 Ps with objectively increased compartmental pressure is the most reliable indicator for an accurate diagnosis of compartment syndrome³⁾. However, if all 5 Ps are observed in patients, compartment syndrome has progressed to a stage where all structures within the compartments have already been damaged. Therefore, when early or impending signs of compartment syndrome are observed, surgeons immedi-

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ately perform decompressive fasciotomy. Even measurement of the compartmental pressure may be omitted to avoid delay in decompressive surgery. We report a case of the early compartment syndrome of the forearm treated by immediate fasciotomy. The aim of this case report is that early decompressive surgery is important for the treatment of compartment syndrome. For diagnosis of compartment syndrome, careful physical examination is necessary.

CASE REPORT

A 57-year-old female patient was transferred to the emergency room from another hospital following the complaint of an injury to the right forearm and hand. Four hours prior, she had undergone a thermal contact burn and compression injury to her right forearm and hand after they were trapped within a hot compress machine for 5 minutes. The patient stated that the temperature of the hot compress machine was less than 60°C. Her right forearm and hand were trapped in the machine, and she could not withdraw her right forearm and hand by herself for 5 minutes. She was barely able to withdraw her right forearm and hand from the hot compress machine with the help of others and using tools.

The main injury to the forearm and hand was located on the volar surface. The injuries were located 3 cm distal from the cubital fossa, a distally rectangular shape on the volar surface of the forearm, wrist, thenar and hypo-

Fig. 1. In the emergency room before fasciotomy. The patient had a thermal contact burn with compression injury after being trapped for 5 minutes in a hot compress machine. The wound was mainly observed on the volar surface of the forearm and hand. On the distal forearm, yellowish eschar was noted. On the hand, erythema and bullae were noted without eschar. The middle fingertip showed alternating color changes synchronized with the heartbeat.

enar eminences on the palm, and volar surfaces of the third and fourth fingers (Fig. 1). The volar surface of her right forearm was burned, erythematous, whitish, and yellow with eschar. The forearm injury was approximately 18×6 cm, and the eschar was located on the distal half of the wound. The eschar was 8×4 cm in size (Fig. 1). The dorsal side of the forearm and hand was relatively intact with mild erythema. The thenar and hypothenar wounds were also erythematous and bullae were noted. On the volar surface of the third and fourth fingers, mainly the proximal and middle phalanges, erythema and small bullae were noted without eschar (Fig. 1).

On physical examination, the motions of the right forearm and hand decreased because of pain, specifically passive extension of the wrist and fingers. Sensations in the forearm and hand decreased, and paresthesia and a tingling sensation were noted. More pain was noted on extension of the fingers than on flexion, but the pain was not severe. The fingertips had pinkish color. The pulse was also detected using handheld Doppler at the fingers. However, at the distal phalanx of the middle finger, the skin color alternatively changed from pink to white (synchronized) with the patient's heart-beat. A simple radiography of the right forearm and hand revealed the absence of bone fractures. An emergency angiogram of the right upper extremity was performed, which showed fo-

Fig. 2. Emergency preoperative angiography of the right upper extremity revealed focal segmental occlusion of the distal portion of the proper palmar artery (radial side) of the right third finger.

cal segmental occlusion of the distal portion of the palmar digital artery (radial side) of the right middle finger (Fig. 2). We did not measure the compartmental pressure because the compartment pressure measurement devices were not well equipped and we had to avoid any delay in treatment.

We diagnosed the patient with impending or early compartment syndrome according to the history, clinical signs, and angiogram findings. Therefore, we planned emergency decompressive surgery for forearm fasciotomy. Approximately 8 hours after injury, emergency escharotomy and fasciotomy were performed on the forearm and wrist. Bullectomies were performed on the hand.

A curvilinear incision was made on the forearm at the center of the wound rather than taking the traditional ulnar or radial approaches. A lazy S incision was performed longitudinally at the center of the forearm wound. The skin and subcutaneous tissue were incised, and an escharotomy was performed. The forearm fascia was subsequently incised longitudinally, avoiding injury to the forearm flexor muscles and median nerve. At the wrist, the carpal tunnel was also released, confirming that the median nerve and flexor tendons were undamaged (Fig. 3). At the distal forearm, the radial artery was exposed by dissection for evaluation of arterial patency. The antegrade and retrograde flows of the radial artery were intact. Bleeding control was performed along the incised wound margins using electrocauterization. However, in the hand, only bullectomies were performed at thenar and hypothenar eminences and the third and fourth fingers without decompressive fasciotomy, because there were no definite eschars or tightness causing hand compartment syndrome. The dorsal side of the right forearm

Fig. 3. Immediate escharotomy and fasciotomy were performed on the forearm and hand along the midline of the wound (8 hours post trauma). The carpal tunnel was also released. In the hand, bullectomies were performed instead of fasciotomy.

and hand were relatively intact, and only mild erythematous change was noted. Therefore, bullectomies or escharotomies were not performed. After saline irrigation of the wound, a gentle compressive wet dressing was used.

After fasciotomy, fingertip circulation was closely observed with hourly checks specifically circulation of the middle finger, for 24 hours. If the fingertip capillary refilling (blanching) test showed abnormal findings, we planned to perform an emergency fasciotomy on the finger following midlateral incision or exploration of the digital arteries. We also carefully and regularly checked the 5 Ps of compartment syndrome (pain, pallor, paresthesia, paralysis, and pulselessness). However, the fingertip circulation remained intact, and color changes of the middle fingertip subsided gradually and were absent 24 hours after emergency fasciotomy of the forearm. The pain on motion of the hand and forearm did not progress, but gradually decreased, except for wound pain. To prevent intravascular thrombosis, heparin injection was administered for 7 days and aspirin was administered for 7 days.

Daily saline irrigation and a wet soaking dressing on the forearm and hand were used due to progressive necrosis of the wound. Debridement was performed several times over the 3 weeks before flap coverage. Finally, an 18×12 cm skin and soft tissue defect was noted on the forearm wound. The hand wound only had skin defects, a 6×3 cm defect on the thenar eminence, 5×2.5 cm defect on the hypothenar eminence, and a 4×2 cm defect on each of the third and fourth fingers (Fig. 4).

The forearm flexor muscles were exposed longitudinally at the central portion of the injury, and the subcutaneous fat was exposed marginally. After fasciotomy, over 2 weeks, using daily dressing and several debridements, the wound had gradually become cleaner. We applied negative pressure wound therapy to the forearm wound

Fig. 4. Three weeks after emergency escharotomy and fasciotomy. Debridement and negative pressure wound therapy were performed several times.

for 1 week. Granulating tissue was noted at the wound at 3 weeks after emergency fasciotomy; therefore, we planned an anterolateral thigh (ALT) perforator free flap to treat the forearm and wrist, and split-thickness skin graft (STSG) to treat the hand.

Three weeks after emergency fasciotomy, under general anesthesia, debridement and coverage using an ALT perforator free flap on the right forearm and STSG on the hand were performed. The 10×30 cm ALT perforator flap was harvested from the patient's right thigh. There were three perforators in the harvested flap, and the middle one was used as a donor artery and vein (Fig. 5). One artery and two veins were anastomosed to the recipient vessels using the end-to-end method. The recipient vessels were recurrent radial artery and veins at the cubital

Fig. 5. The anterolateral thigh perforator free flap was performed 3 weeks after emergency fasciotomy. The harvested flap size was 10×30 cm, and the middle among the three perforators was used as a donor vessel.

Fig. 6. Three days after the anterolateral thigh perforator free flap on the forearm and split-thickness skin graft on the hand. The flap was well perfused, and the skin graft showed good uptake.

fossa. STSG was performed on the thenar and hypothenar eminences and third and fourth fingers. The donor site wound on the right thigh was closed primarily with a skin graft (3×4 cm in size). Postoperatively, the flap survived well, and the skin graft showed good uptake (Fig. 6).

Three weeks after the free flap and skin graft were performed, active and passive motion of the forearm, wrist, and hand was started. At 6 weeks, the full range of motion (ROM) could be used. Six months after the free flap, the ROM of the right elbow, wrist and hand was good (Fig. 7, 8). The hand intrinsic muscle function was also good. No neurologic deficit was found on her right forearm and hand. Twelve months postoperatively, a debulking procedure was performed on the flap for esthetic shaping.

DISCUSSION

Compartment syndrome is the group of clinical signs and symptoms associated with elevated interstitial tissue

Fig. 7. Six months after the anterolateral thigh free flap and skin graft.

Fig. 8. Six months after the anterolateral thigh free flap and skin graft. The range of motion of the wrist and hand was normal, and the intrinsic muscle functions of the hand were good. We planned a debulking procedure for the flap.

pressure within a rigid, limited space called a compartment¹⁾. The causes of compartment syndrome are fracture, soft tissue injury, arterial injury, drug (limb compression), burns, crush injuries, penetrating trauma, constrictive dressings or casts, infections, bleeding disorders, extravasations of drugs or intravenous fluids, and reperfusion injury, among others^{1,4)}. The forearms and lower legs are the most frequent sites of compartment syndrome. The forearm is the most common site for compartment syndrome in the upper extremities. The causes of forearm compartment syndrome are supracondylar fractures of the humerus in pediatric patients, distal radius fractures, malfunctioning pneumatic tourniquets, intravenous line extravasations, hematomas, and infections^{3,5)}. Early diagnosis and fasciotomy are the standard of care for upper extremity compartment syndrome and may prevent the development of irreversible contractures of the forearm and hand musculature and damage to the nerves as observed in VIC^{2,3)}.

This patient had a traumatic injury of the right forearm and hand after being trapped by a hot compress machine for 5 minutes. The thermal burn combined with compression injury aggravated intramuscular edema; burned skin loses elasticity and hinders tissue expansion, acting like an overly tight dressing¹⁾. On physical examination of the hand and forearm, 4 hours after trauma, all 5 Ps except pulselessness were observed.

The pain was more than would be expected based on the wound itself. Moreover, more pain was noted on passive stretching of the hand (fingers) and forearm muscles than active motion, which is the characteristics of the earliest clinical symptoms of forearm compartment syndrome^{2,6,7)}. In the emergency room, we must identify that the causes of color changes of the middle fingertip occurring with the heart-beat.

If the causes of color changes of the middle fingertip were due to the injuries of the palmar digital arteries, emergency exploration of the hand was necessary. Forearm fasciotomy would not be effective for this phenomenon. If the digital arteries were injured, we had to explore the digital vessels in the right hand at the same time of the forearm fasciotomy or instead of the forearm fasciotomy. Therefore, we decided to do emergency angiography of the right upper extremity, considering the

delay in emergency fasciotomy.

Emergency angiography of the right upper extremity was performed 6 hours after trauma, and revealed focal segmental occlusion of the distal portion of the palmar digital artery (radial side) of the right third finger (Fig. 2).

Therefore, we concluded that the color changes of the middle fingertip were mainly due to injury or compression of the radial and ulnar arteries by impending compartment syndrome in the forearm, not only by a single finger or hand injury. This objective finding was helpful to us for the diagnosis of the forearm compartment syndrome. If we neglected the color changes of the middle fingertip during the physical examinations in the emergency room, immediate fasciotomy might be delayed causing ischemic damages of the muscles and nerve.

After emergency upper extremity angiogram was performed, 6 hours after trauma, we had to decide whether to perform immediate fasciotomy or perform further observation. We diagnosed the patient with impending compartment syndrome or early stage compartment syndrome considering the mechanism of injury (thermal burn with compression injury), eschar on the distal forearm, the presence of 5 Ps (pain, pallor, paresthesia, intermittent periodic pulselessness of the middle finger, mild paralysis), color changes of the middle finger, and focal segmental occlusion of the distal portion of the proper palmar artery of the right third finger on angiography.

At that time, if we measured the intracompartmental pressure of the forearm, we could diagnose compartment syndrome more accurately. However, we had to prepare and perform emergency decompressive surgery to avoid any delay in management caused by measuring the compartment pressure.

There are some reports that measurement of the intracompartmental pressure is another available method for the diagnosis of compartment syndrome. The normal resting pressure in an adult forearm has been reported to be 8 to 9 mmHg^{3,4)}. Some clinicians accept the diagnosis of compartment syndrome if the absolute pressure in the compartment is greater than 30 mmHg⁴⁾. Additionally, we would use more objective data following the Whitesides' method to calculate delta-P value. Delta-P values could be obtained by determining the difference in diastolic

blood pressure and intracompartmental pressure. If the delta-P value was lower than 30 mmHg, compartment syndrome would be suspected⁸⁾. However, compartment syndrome cannot be diagnosed using delta-P value or intracompartmental pressure alone. It should be noted that these numerical values are not hard and fast and should be corroborated with clinical examination findings to determine the presence or absence of compartment syndrome and the need for operative decompression³⁾.

But, in polytrauma patients with associated head injury, drug and alcohol intoxication, intubation, spinal injuries, use of paralyzing drugs, extremes of age, unconsciousness, or low diastolic pressures, measuring compartment pressures may be of use in determining the need for fasciotomy.

There are some compartment pressure measurement devices, including the continuous-infusion pressure transducer and commercially available compartment pressure monitor³⁾, handheld manometer (Stryker), and mercury manometer⁷⁾. Imaging studies including ultrasound, computed tomography, and magnetic resonance imaging, are usually omitted to prevent any delay in treatment⁷⁾.

Some have reported the presence of three clinical signs and symptoms (among the 5 Ps including disproportionate pain and pain with passive stretching of the fingers), indicating a greater than 90% probability that compartment syndrome is present⁴⁾. They reported that disproportionate pain and pain with passive stretching of the fingers are considered the first and most sensitive signs of compartment syndrome in a conscious patient. According to this report, in this patient, there was a greater than 90% probability that compartment syndrome was present⁴⁾.

A study assessing the association between the duration of ischemia and degree of damage to the muscle and nerves was previously conducted^{4,7)}. If compartmental release was performed within 4 hours of onset, nerve conduction velocity always returned to normal regardless of the amount of pressure applied or the length of time the pressure was applied. However, the release was performed after 12 hours, nerve conduction velocity did not return to normal for any pressure or time condition. They showed that after 4 hours of muscle ischemia, less than 5% of muscle cells were damaged; however, if ischemia

time was prolonged to 8 hours, then nearly 100% of muscle cells were damaged⁴⁾. Considering these consequences, there is little negative risk to fasciotomy except for an unsightly scar.

We performed fasciotomy using a lazy S incision longitudinally along the midline of the wound for direct release of the compress lesions instead of the traditional ulnar or radial incision approaches³⁾ (Fig. 4). This midline lazy S incision method was more convenient for visualizing the injured areas than the radial or ulnar approach method. We did not extend the incision to the antecubital fossa or proximally to the elbow because there was no injury in this area (Fig. 3). The forearm has three compartments: dorsal, superficial and deep volar, and the mobile wad³⁾. We performed a single volar incision rather than a dorsal incision. Some investigators have advocated that complete forearm decompression can be accomplished using a single volar incision^{6,9,10)}. This volar single incision decreased the elevated compartment pressure in the volar, dorsal and mobile wad compartments to near-baseline levels after 10 minutes⁶⁾. Some authors suggest that adequate decompression of the forearm requires the fascial release of both the dorsal and volar compartments⁴⁾. We would also incise the dorsum of the right forearm if compression symptoms were aggravated on the dorsal side of the forearm. The carpal tunnel was also released in this patient to the compression of the median nerve and flexor tendons, specifically for the release of symptoms of paresthesia. If compartment syndrome had appeared in the hand or the color of the middle finger changed to white or intrinsic muscle action disturbances occurred, we would have performed a fasciotomy on the dorsum of the hand or fingers.

Three weeks after emergency fasciotomy, healthy granulation tissue grew, but the flexor muscles and tendons were exposed in the forearm (Fig. 4). Therefore, we performed ALT perforator free flap coverage with a skin graft (Fig. 6). If the muscles and tendons were not exposed in the forearm, a human allogeneic dermal graft with STSG would have been appropriate. The flexor digitorum profundus (FDP) and flexor pollicis longus (FPL) muscles and median nerve are usually severely and frequently affected by compartment syndrome⁵⁾. In this patient, the function of FDP and FPL was good 6 months

postoperatively. The function of the median nerve was also good based on the examination of hand sensation and intrinsic muscle function (Fig. 7, 8).

As a result, we regarded that our decision of immediate fasciotomy was appropriate in this patient. The limitation of this case report is that there was no compartmental pressure measurement of the forearm in this patient.

In conclusion, immediate and early decompressive fasciotomy is important not only in definite forearm compartment syndrome, but also in impending forearm compartment syndrome to avoid ischemic necrosis of the forearm muscles and nerves. The clinical signs and symptoms (5 Ps) of the compartment syndrome are the most reliable for the diagnosis and determining of early decompressive surgery of the compartment syndrome, especially when it is difficult to measure the compartmental pressure due to insufficient devices or time consuming. Therefore, close observation and precise evaluation of 5 Ps via physical examination are necessary in the forearm compartment syndrome.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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