Case report
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Compartment syndrome due to extravasation of peripheral parenteral nutrition: extravasation injury of parenteral nutrition

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Compartment syndrome is a rare but devastating condition that can result in permanent neuromuscular or soft tissue injuries. Extravasation injuries, among the iatrogenic causes of compartment syndrome, occur under a wide variety of circumstances in the inpatient setting. Total parenteral nutrition via a peripheral route is an effective alternative for the management of critically ill children who do not obtain adequate nutrition via the oral route. However, there is an inherent risk of extravasation, which can cause compartment syndrome, especially when detected at a later stage. Herein, we report a rare case of compartment syndrome and skin necrosis due to extravasation, requiring emergency fasciotomy and skin graft in a 7-month-old boy who was treated with peripheral parenteral nutrition via a pressurized infusion pump. Although we cannot estimate the exact time at which extravasation occurred, the extent and degree of the wound suggest that the ischemic insult was prolonged, lasting for several hours. Pediatric clinicians and medical teams should carefully examine the site of insertion of the intravenous catheter, especially in patients receiving parenteral nutrition via a peripheral intravenous catheter with a pressurized infusion pump.

Key words: Compartment syndromes, Extravasation, Infusion pumps, Parenteral nutrition, Skin transplantation

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Introduction

Compartment syndrome is a rare but devastating condition that can result in permanent neuromuscular injury, skin loss, and limb amputation[1]. It is most commonly associated with trauma, although cases of nontraumatic and iatrogenic origin are increasing[2]. There are many iatrogenic causes, including the use of a tourniquet[2], pressurized infusion pumps[3], extravasation of various kinds of medications[2,4], and anticoagulation therapy[2]. One of the iatrogenic causes of compartment syndrome, extravasation injuries, occurs under a wide variety of circumstances in the inpatient setting[2]. Among the accidental extravasation injuries, those associated with total parenteral nutrition (TPN) are the most commonly reported in newborns in the intensive care unit setting[5]. TPN is commonly used for nutritional support in the management of critically ill children who cannot be adequately fed. TPN can be categorized as a vesicant, which is a hyperosmolar, acidic, and polar solution with a high concentration of ionic substances[4]. Because of these characteristics, it can aggravate soft tissue injury when extravasation occurs[4].

Several factors increase the susceptibility to extravasation injury in pediatric patients[5].

The veins of pediatric patients are short, small in vascular caliber, and fragile[6], which makes extravasation occurs more often. And extravasation is usually detected later than in adults because of the inability to communicate clearly, and because of several layers of bandages covering the catheter insertion site to secure the catheter in place[6].

In the present study, we report a rare case of compartment syndrome and skin necrosis due to extravasation requiring emergency fasciotomy and skin graft in a 7-month-old boy who was treated with peripheral parenteral nutrition via a pressurized infusion pump, which had not been reported in Korea before. Pediatric clinicians and medical teams should carefully examine the site of insertion of the intravenous catheter, especially in patients receiving parenteral nutrition via peripheral intravenous catheter with a pressurized infusion pump.

Case report

A 7-month-old boy who had undergone surgery for a tracheoesophageal fistula and esophageal atresia at 1 day of age was admitted to our hospital for treatment of respiratory syncytial viral pneumonia. He was afebrile, but showed recurrent cough and sputum. He looked ill and mildly lethargic. Breath sounds were coarse with wheezing and crackles on both the lower lung fields. Results of respiratory specimen analysis were positive for respiratory syncytial virus, and the chest radiograph showed increased peribronchial infiltration and air bronchogram. After admission, cough and posttussive vomiting became more severe with chest physiotherapy and oral feeding. Because oral feeding in the presence of severe coughing or vomiting can increase the likelihood of aspiration pneumonia, oral feeding was discontinued and parenteral nutrition was administered via the peripheral venous route. We decided to start TPN via peripheral route which was less invasive than central TPN requiring central line insertion, expecting the period of non per os would not be long. The peripheral TPN was a ready-to-use formula, containing 22.5 g of protein per liter, 60 g of dextrose per liter, and 279 kcal in 1 bag of 533.1 mL. It was hyperosmolar averaging 900 mOsm/L, had a pH of 6.5, and consisted of a polar solution containing a large amount of ionic substances, including 37 mEq of sodium per liter, 30 mEq of potassium per liter, 20 mEq of calcium per liter, 51 mEq of acetate per liter, 10 mEq of phosphate per liter. The PN solution was infused through a 24-gauge intravenous silicon catheter on the first day of admission, and the catheter was replaced with a new one every 1 or 2 days. On day 1, TPN was infused by 11 mL/hr, and 20% SMOFlipid was infused by 1 mL/hr. From second day of admission, the PN solution had been infused by 20 mL/hr, and 20% SMOFlipid was infused by 2 mL/hr. On day 6, a 24-gauge intravenous catheter was newly inserted into the dorsal cephalic vein at the dorsum of the patient's right hand. After 8 hours since IV insertion, the patient showed signs of irritability, and the obstruction alarm of the infusion pump was triggered. After confirming that there were no focal signs such as erythema, edema, or tenderness indicating extravasation around the IV insertion site, the nurse on duty repositioned the intravenous catheter, fixed the site with tape, and put several bandages for firm fixation. Approximately 9 hours after the repositioning of the intravenous catheter, without any alarm sign, the patient's right hand and arm appeared severely swollen, and capillary refill was absent. At the catheter insertion site, the patient's skin was pale and dark red with several blisters observed under the catheter (Fig. 1).

An emergency fasciotomy was performed under the suspicion of compartment syndrome (Fig. 2). An orthopedic surgeon sutured the fascia after irrigating the area several times with saline solution. Delayed primary skin closure was performed 8 days after the fasciotomy, at which point a black and thick eschar had developed because of skin necrosis extending from the back of the

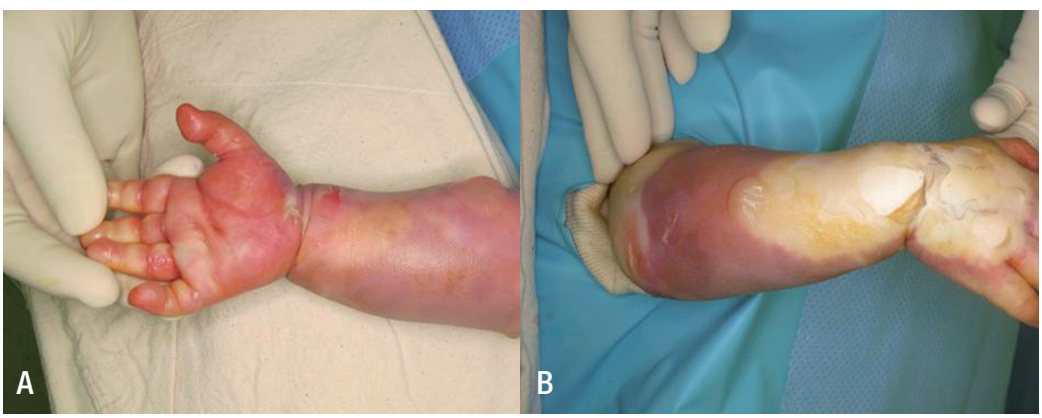

Fig. 1. (A) The volar side of the forearm turned dark red and was severely swollen, along with the occurrence of blisters. (B) The dorsal side of the forearm around the catheter insertion site turned whitish, and it showed ischemic changes for a long period.

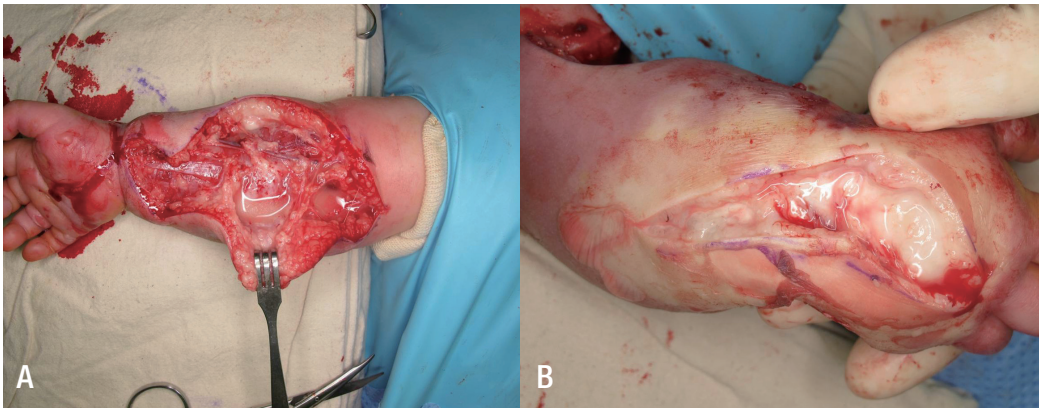

Fig. 2. (A) The volar side of the forearm contained a liquid, assumed the extravasated fluid. (B) The dorsal side of the forearm showing the zig-zag skin incision.

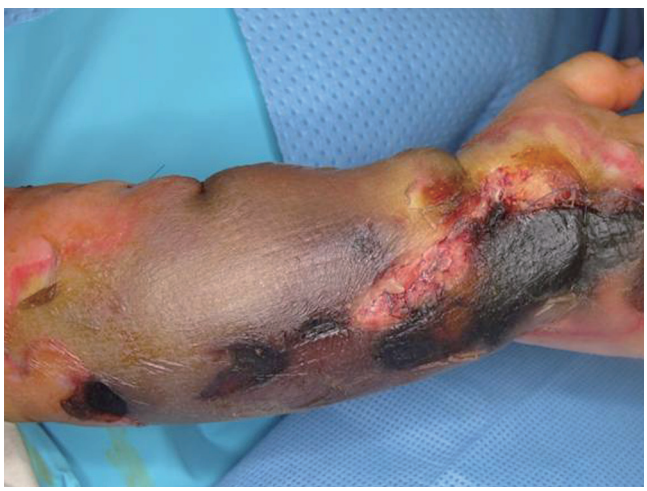

Fig. 3. Thick necrosis formed from the back of the hand to the forearm including the wrist joint, with increased risk of wrist joint contracture.

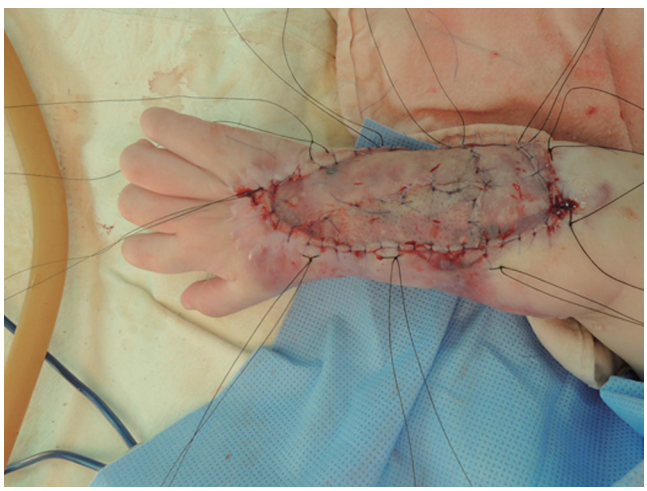

Fig. 4. We performed an operation to cover the lesion with a full-thickness skin graft. This picture shows the skin graft covering the lesion.

patient's hand to the forearm area (Fig. 3). A skin graft was scheduled for treatment of the skin necrosis after melting and debriding the necrotic tissue with a moist dressing. Because the extent of necrosis was from the back of the patient's hand to the forearm, including the wrist joint, there was a high chance of wrist joint contracture before the planned skin graft. Therefore, the patient was assessed for sensory and motor function, and subjected to rehabilitation treatment consisting of wrist articulation exercises. Skin graft surgery was delayed because of pneumonia, which was diagnosed during his regular wound dressing and rehabilitation treatment. It was performed 4 months after the extravasation event (Fig. 4). At the time of this report, skin engraftment had been successfully completed, and the patient was receiving continued rehabilitation treatment (Fig. 5).

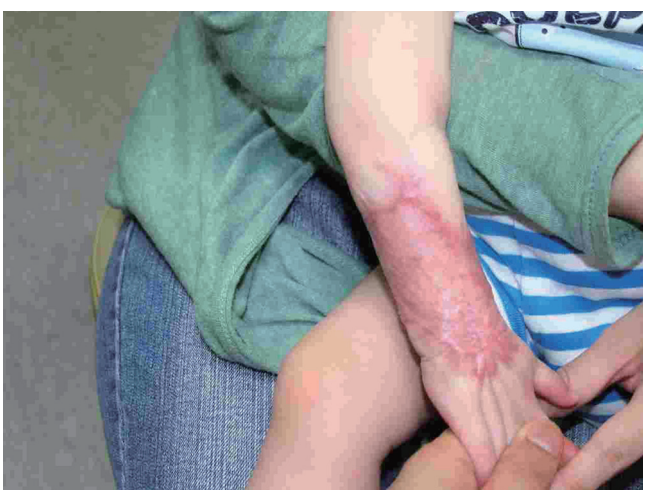

Fig. 5. This picture shows the healed lesion; skin engraftment was successful 98 days after transplanting the skin graft.

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Discussion

Acute compartment syndrome is a potentially severe and devastating condition in which increased pressure within a limited space impedes circulation and disrupts the function of the tissues within that space[1,3].

Extravasation injuries, which are among the iatrogenic causes of compartment syndrome, occur under a wide variety of circumstances in the inpatient setting[2]. Extravasation injury occurs when fluid from an intravenous line leaks into the extravascular space[6]. In the present case, the extravasation of TPN resulted in compartment syndrome and skin necrosis, decreasing local blood flow and perfusion.

In the pathophysiology of compartment syndrome, the arteriovenous pressure gradient theory proposed by Matsen and Krugmire[7], which was published in 1978, is the most widely accepted hypothesis. Increased pressure in a limited space impairs microcirculation, resulting in an ischemic state[7]. Once the ischemia is triggered, neural injury begins after 30 minutes of ischemia and becomes irreversible after 12 hours[3,7]. The permeability of the capillary endothelium increases after approximately 3 hours of ischemia, and muscle changes begin after approximately 2 hours, becoming irreversible after 4 hours of ischemia[3,7]. In our case, the extent and degree of the wound suggest that the ischemic insult was prolonged, lasting for several hours, although we cannot estimate the exact time of extravasation.

In the present case, several factors adversely affected the local blood flow and tissue perfusion, resulting in compartment syndrome and massive skin necrosis that extended from the dorsal side of hand to the forearm.

First, the risk of extravasation is higher when TPN is administered via a peripheral intravenous catheter than via a central venous catheter[5]. Peripheral parenteral nutrition is commonly used for nutritional supportive therapy in patients who cannot eat well in a short period of time[5]. It does not require a complex procedure in pediatric patients for accessing a central venous catheter such as sedation or ultrasonography, and is not usually accompanied by complications associated with the use of the central vein catheter such as central catheter-induced sepsis, central venous thrombosis, or complications associated with the procedure itself (bleeding, pneumothorax, local infection, etc.)[5]. Because of these advantages, the indications for peripheral nutritional support are increasing in the clinical field[5]. However, when it is administered via the peripheral intravenous route, there is a high likelihood of phlebitis or extravasation, and replacement of the catheter is required every 2 to 3 days, which makes it unavoidable to puncture the veins repeatedly[6]. This exacerbates blood vessel conditions, creating a higher possibility of extravasation[6]. It is possible that the worsened vein condition caused by the repetitive insertion of the intravenous catheter may have increased the risk of extravasation in the present case.

Second, TPN itself can aggravate soft tissue injury when extravasation occurs[8]. Extravasates are divided into irritants and vesicants based on their potential for local toxicity[2]. An irritant can cause an inflammatory reaction, characterized by warmth, erythema, and tenderness; however, it is not directly toxic to the tissue[2]. Vesicants are agents that have the potential to cause blistering, sloughing of the skin, and varying degrees of deep tissue damage because they are inherently toxic[8]. Extravasation of parenteral nutrition, which is a type of vesicant, can itself aggravate soft tissue injury independently of the presence of compartment syndrome[2]. The soft tissue injury that occurs as a result of the extravasate is linked to 4 factors: the osmolarity of the extravasate, the inherent cytotoxicity of the extravasate, the infusion pressure, and possible vasoconstrictive properties of the extravasate[8]. In our case, the parenteral nutrition, a complex mixture of substances including nitrogen, dextrose, lipids, electrolytes including potassium and calcium, vitamins, and trace elements, was hyperosmolar (averaging 650 mOsm/L). It had a pH of 6.5 and consisted of a polar solution containing a large amount of ionic substances. The proposed mechanism of local tissue toxicity is suggested to be a combination of the toxic effects of the local ions, hyperosmolarity, and the acidic pH of the solution[2]. The fact that we were unable to avoid a skin graft, despite immediate fasciotomy and massive irrigation to eliminate the extravasate, supports that the damage was caused by one of the above-mentioned factors.

Third, the use of a pressurized infusion pump contributes to the development of compartment syndrome when extravasation occurs[3]. The pressurized infusion pump is a medical device that applies pressure at a consistent speed to inject fluid, and measures the fluid collected from the chamber of the intravenous infusion set[9]. The pressurized infusion pump is currently used extensively for pediatric patients whose volume of distribution is small and who require a more precise adjustment of the rate of fluid injection[9]. Despite this advantage, it has a risk of infusing fluid continuously even when the internal pressure increases because of extravasation in an enclosed space[3]. When intracompartmental pressure is elevated, a pressurized infusion pump would be able to infuse a predetermined amount of fluid by increasing the pressure of infusion, even without triggering the obstruction alarm, whereas intravenous drip injections that act by gravity would not be able to continue to inject in normal capacity or otherwise would have a back flow of fluid[3,9].

Fourth, pediatric patients are vulnerable to both extravasation and compartment syndrome because these can remain undetected or be detected late without a warning[6]. In younger children who cannot clearly communicate regarding pain at the local site, edema, or heat sensations, and can only express via nonspecific whining or crying, a distinction between extravasation and

common irritability is difficult[10]. And the veins of pediatric patients are short, small in vascular caliber, and fragile, which makes extravasation occurs more often[10]. Moreover, younger children have a larger amount of subcutaneous fat than adults, which makes it difficult to detect local edema until a lot of fluid is extravasated. Furthermore, in pediatric patients, it is common to place several layers of tape, bandages, or even splints on the catheter insertion site to secure the catheter in its place because it is not easy to access the peripheral venous route and to maintain it because of poor cooperation. The several layers of bandages could mask the extravasation, making the detection of extravasation late.

The characteristics of the present case reflect the progress and consequences of extravasation and compartment syndrome. Although muscular necrosis and loss of motor function could be prevented by immediate fasciotomy, delayed complications such as skin necrosis and wrist joint contracture could not be avoided. As a result, the patient required a skin graft, rehabilitation, and prolonged assessment of sensorineural and motor function, which would be otherwise unnecessary. In addition to parenteral nutrition, several intravenous infusion medications can act as irritants and vesicants including chemotherapeutic agents, intravenous immunoglobulin, contrast media, and vasopressor drugs such as dopamine, arginine, and phenytoin[2,10].

Early detection and prevention of extravasation is the best way to avoid soft tissue injuries during infusion irritants and vesicants[2]. For reducing the extravasation injuries, we recommend to puncture the proper vein once when making an intravenous route[6]. Puncturing the veins repeatedly exacerbates blood vessel conditions, creating a higher possibility of extravasation[6]. Small vessels cannot endure the velocity of intravenous drugs and the pressure of infusion pump, so large and straight vessels are preferred in the side of extensor, such as dorsum of hand[6].

Pediatric doctors and medical teams should specifically check the site of insertion of the intravenous catheter carefully, especially when infusing irritants and vesicants via the peripheral intravenous catheter using a pressurized infusion pump. And if extravasation occurs, immediate catheter removal and rapid decision for the treatment are important for minimizing the extravasation injuries.

Conflict of interest

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

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