



Comparison of lower extremity fasciotomy wound closure techniques in children: vacuum-assisted closure device versus temporary synthetic skin replacement

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Abstract

Purpose No clear consensus on the optimal treatment of fasciotomy wounds due to acute compartment syndrome of the lower leg in children exists. We therefore compared two commonly used methods to close fasciotomy wounds, Epigard, a temporary synthetic skin replacement (SSR) and the vacuum-assisted closure (V.A.C.) device, in respect of treatment duration and complication rates.

Methods We studied the cases of 27 patients who were treated at our institution for acute compartment syndrome of the lower leg with a fasciotomy over a 10-year period. The fasciotomy wound was either treated with SSR or V.A.C. device. We recorded the number of procedures to definitive wound closure, days to wound closure, hospitalization days and sequelae rate.

Results In the V.A.C. device group (18 patients) the mean number of procedures until definitive wound closure was 3.1, mean days until wound closure was 9.4 and mean days of hospitalization was 16.2. One patient suffered from a wound infection and one patient required a full thickness skin graft. In the SSR group (9 patients), the mean number of procedures was 1.8, mean days until definitive wound closure was 4.9 and mean days of hospitalization was 9.9. No sequelae were recorded. There was a statistically significant smaller number of procedures (p value 0.018), fewer days to definitive wound closure (p value 0.002) and fewer hospitalization days (p value 0.005) in the SSR group.

Conclusions Both SSR and V.A.C. device are safe and reliable for closure of fasciotomy wounds in children, whereas SSR seems to lead to shorter time until definitive wound closure.

Keywords Compartment syndrome · Lower extremity · Child · Fasciotomy · V.A.C. device

Introduction

Compartment syndrome is a well-known phenomenon and was first described in 1881 by von Volkmann [1]. It describes a pressure elevation in a closed compartment leading to compromised vascular supply of the affected compartment and ultimately ischemia and necrosis of the affected muscles. It is most often a sequela of trauma to the lower extremities. Contrary to prior belief compartment syndrome

in children is quite common, affecting up to 11% of all pediatric patients with a tibial fracture [2]. The treatment of compartment syndrome is undisputed and consists of an urgent fasciotomy of the affected limb. In respect to the dressing of the fasciotomy wound, however, no clear consensus to the best method in children exists. At our institution, the two most commonly used methods are staged wound closure by means of a V.A.C.[®] device (KCI, San Antonio TX, USA) (Fig. 1) and staged wound closure with the help of a temporary synthetic skin replacement (SSR), Epigard[®] (Consept AG, Eschbach, Germany) (Fig. 2).

The aim of this study is to compare the two methods most commonly used in our institution, V.A.C. device and SSR, in regard to the number of necessary procedures until definitive fasciotomy wound closure could be performed. Secondary endpoints were the number of days until definitive wound

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Fig. 1 Fasciotomy wound of the lower leg closed with a vacuum-assisted closure device



Fig. 2 Fasciotomy wound of the lower leg closed with synthetic skin replacement, Epigard

closure, hospitalization duration and the sequelae rate of fasciotomy, as well as of the compartment syndrome itself.

Methods and materials

After receiving approval from the local ethics committee, we used our internal medical database to identify patients with acute compartment syndrome of the lower leg who were treated between January 2005 and September 2015 at our institution. We included all patients who were treated by fasciotomy and in whom the wound was covered either with SSR or a V.A.C. device. Fasciotomy was performed either on clinical suspicion or if a compartment pressure measurement by needle manometry was greater than 30 mmHg [3].

The decision which compartments to open was made by the lead surgeon based on etiology of the compartment syndrome, clinical appearance, intraoperative findings and—if applicable—compartment measurements. The choice of dressing was also made by the lead surgeon—who was either a general pediatric surgeon or pediatric orthopedic surgeon—depending on the before mentioned factors.

If SSR is used the wound is covered with SSR cut to wound size. A dressing change is performed every 48 h, at which the SSR's size may be reduced until the wound can be closed completely. When a V.A.C. device is used, it may be installed at initial fasciotomy or at the first dressing change of a wound initially covered with SSR.

We excluded all patients who suffered from a polytrauma and patients with an ischemic or systemic illness, e.g., meningococcal sepsis, since the underlying co-morbidities could cause bias towards longer hospitalization and wound healing.

The following patient data was collected: number of necessary procedures until definitive wound closure was obtained, the dates of these procedures, the date of wound closure, length of stay at the hospital and the sequelae of both fasciotomy (i.e., wound infections, need of skin graft) and compartment syndrome (i.e., loss of sensation or function). Also, we reviewed the number of compartments that were opened, the compartment pressures if applicable and the etiology of the compartment syndrome.

All compartment pressure measurements were made with the Stryker® Intra-compartmental Pressure Monitor (Kalamazoo, MI, USA).

The data analyzes were performed using the statistical software R, version 3.1.3 (R Foundation for Statistical Computing).

Results

Over the 10-year period, we identified 45 patients who had been treated at our institution for compartment syndrome of the lower extremities. Twenty-seven patients met the criteria for the study with 28 affected lower extremities. We excluded 18 patients: 6 due to systemic illness leading to compartment syndrome, 4 due to polytrauma, 3 due to ischemic problems leading to compartment syndrome (e.g., ECMO-cannula) and 5 patients due to other reasons: one patient was treated for chronic compartment syndrome, informed consent could not be obtained for three other patients and one patients wound was closed primarily, due to the intraoperative findings being more consistent with postoperative bleeding rather than a compartment syndrome (Fig. 3).

Our patients had a mean age of 11.18 years and 74% ($n = 20$) of them were boys. The most common etiology of the compartment syndrome was fractures of the lower leg followed by tibial derotational osteotomies to treat torsional deformities. There were no statistically significant differences between the V.A.C. device and the SSR group concerning these characteristics. The incidence of compartment syndrome of the lower leg was 4% of all patients hospitalized from January 2005 to September 2015 for fractures of

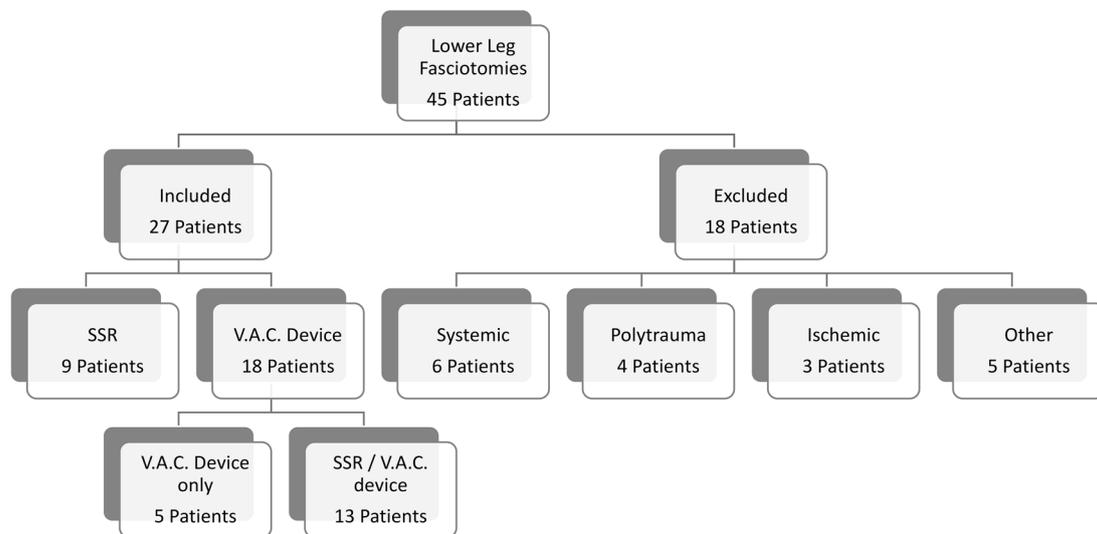


Fig. 3 Included and excluded patients. V.A.C. device vacuum-assisted closure device, SSR synthetic skin replacement

the lower leg and 3.8% of all patients treated for torsional deformities. This is a lower incidence than previously described in literature [2].

The V.A.C. device group consisted of 18 patients with 19 affected lower legs, whereof most (13 patients) were initially treated with SSR and at the first dressing change a V.A.C. device was installed. All other patients were treated with a V.A.C. device from the initial fasciotomy. In this group a compartment pressure measurement was made in 8 patients prior to fasciotomy and 6 patients showed a pressure greater than 30 mmHg in at least one of the measured compartments. A medial fasciotomy alone (meaning the dorsal compartments were opened) was performed on 2 patients, a lateral fasciotomy (meaning the anterior and lateral compartments were opened) on 9 patients (10 lower legs) and a double incision fasciotomy (meaning all four compartments were opened) on 7 patients. The mean number of procedures until wound closure was 3.05 procedures. The mean number of days between procedures was 3.02. The mean number of days until the wound was closed was 9.37 days, whereas the mean number of days the child was hospitalized was 16.21 days. One patient sustained a wound infection. He was treated with intravenous antibiotics, as well as early removal of the osteosynthesis material and wound debridement. One patients wound had to be closed with a full thickness skin graft. Six patients experienced sequelae as a result to the compartment syndrome itself, whereas three patients had more than one complication. Four patients suffered from transient partial loss of function of the extensors of the lower leg. Two patients suffered from transient partial loss of distal sensation. One patient showed a contraction of the hallucis longus flexor muscle, which was completely reversible with physical therapy. Two patients suffered from permanent loss

of function: one patient has an extension deficit of the hallux (M2 on the Oxford Muscle Strength Grade Scale [4]), the other patient has an extension deficit of the foot (M3). Mean follow-up time was 27.2 months.

The SSR group consisted of 9 patients with 9 affected lower legs and all patients were treated exclusively with SSR from fasciotomy to wound closure. In this group a compartment pressure measurement was made in 4 patients prior to fasciotomy and one patient showed a pressure greater than 30 mmHg in at least one of the measured compartments. A medial fasciotomy was performed on one patient, a lateral fasciotomy on 7 patients and a double incision fasciotomy on one patient. The mean number of procedures until definitive wound closure was 1.78 procedures. The mean number of days between procedures was 2.69. The mean number of days until wound closure was 4.89 days, whereas the mean number of days the child was hospitalized was 9.89 days. No wound infection was recorded in this group and there was no need for skin grafts. However, one patient suffered from ongoing pain after fasciotomy that necessitated a reoperation with further opening of the skin, the compartments were sufficiently open at fascia level. Two patients experienced transient sequelae due to compartment syndrome, which were in one case a transient partial loss of function of the extensor of the hallux and one transient partial loss of distal sensation. One patient suffered from a permanent loss of function of the extensor of the hallux (M1). Mean follow-up time was 25.2 months.

Comparison of the V.A.C. device group and the SSR group showed significantly shorter duration of time until definitive wound closure was achieved (two sided *t* test, *p* value 0.002), as well as significantly lower number of follow-up procedures (two sided *t* test, *p* value 0.018) and

Table 1 Comparison of V.A.C. device and SSR groups

	V.A.C. device ($n=19$)	SSR ($n=9$)	p value (two sided t test, 0.95 confidence level)
Mean age (SD)	10.63 (2.68)	12.35 (3.32)	0.199
Hospitalization days (SD)	16.21 (6.10)	9.89 (4.34)	0.005*
Number of follow-up operations (SD)	3.05 (1.47)	1.78 (1.09)	0.018*
Days to wound closure (SD)	9.37 (4.67)	4.89 (2.32)	0.002*
Wound infections	1	–	
Need for skin graft	1	–	

SD standard deviation, V.A.C. device vacuum-assisted closure device, SSR synthetic skin replacement
 p value significant \leq or $<0.05^*$

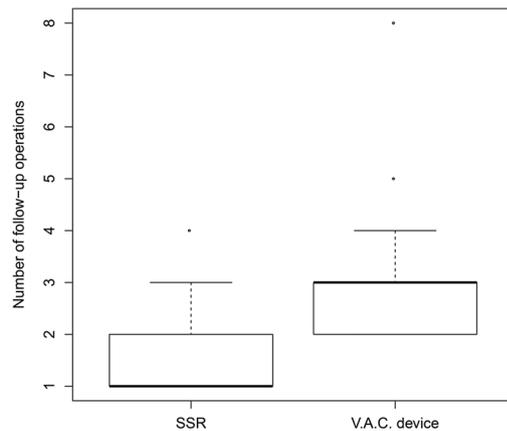


Fig. 4 Boxplot showing statistically lower number of follow-up operations for the SSR group compared to the V.A.C. group ($p=0.018$), whereas the box represents the middle 50% of all datapoints and the bold stripe represents the median. V.A.C. device vacuum-assisted closure device, SSR synthetic skin replacement

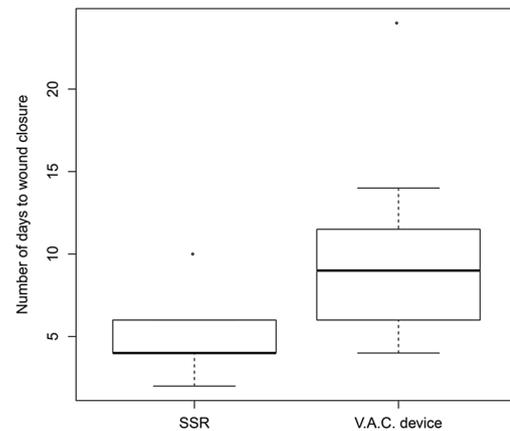


Fig. 5 Boxplot showing statistically lower number of days to wound closure for the SSR group compared to the V.A.C. group ($p=0.002$), whereas the box represents the middle 50% of all datapoints and the bold stripe represents the median. V.A.C. device vacuum-assisted closure device, SSR synthetic skin replacement

hospitalization days (two sided t test, p value 0.005) for the SSR group (Table 1; Figs. 4, 5).

There was no significant difference in duration to definitive wound closure or hospitalization days between patients with a fracture and patients with an osteotomy as etiology of the compartment syndrome. Also, there was no significant difference in days to definitive wound closure or hospitalization duration between patients with single or double incision fasciotomy.

Discussion

Compartment syndrome is a well-known phenomenon in which the initial treatment of fasciotomy is undisputable. However, the following treatment of the fasciotomy wound in children is not so clear.

An ideal dressing for children would provide as few as possible dressing changes—meaning fewer necessary general anesthesia in children—until definitive wound closure

and a short time to wound closure and hence a shorter hospitalization. It has been shown in adults that an increased time to wound closure is associated with persistent sequelae of compartment syndrome [5]. The choice of dressing for the fasciotomy wound may therefore play a crucial role.

Our study could show a significantly shorter time to wound closure, less hospitalization days and fewer necessary follow-up procedures to wound closure for the SSR group.

When compared to the few other pediatric studies about compartment syndrome, our results are in line with a mean procedure rate of 2–4 in fasciotomy wounds in children until definitive wound closure could be achieved [2, 6, 7]. Erdös et al. reviewed 24 patients with compartment syndrome of the lower leg, foot, forearm and hand treated with SSR (Epigard®) in combination with shoelace or a split skin graft, whereas Ferlic reviewed 31 patients with a lower leg fasciotomy treated with a V.A.C. device or SSR (Epigard®) [6, 7]. Neither compared the two techniques.

To the best of our knowledge, this is the first study to compare different treatment options for fasciotomy wounds in children.

Epigard[®], which is commonly known and used in central Europe, is a synthetic skin replacement made of an upper layer consisting of polytetrafluorethylene and a lower layer of soft, elastic polyurethane. The upper layer is permeable to air, yet prevents the passage of bacteria. The lower polyurethane layer is an open matrix which is supposed to clean and condition the wound ground. Epigard[®] is easy to use, as it can readily be cut to fit the wound and then be stapled to the wound edges. It can be used alone or in combination with a classic shoelace technique [6]. It has to be changed every 24–48 h [8]. The underlying wound and extremity may be difficult to assess on ward rounds due to the mostly thick bandage, which is necessary to absorb the wound fluid.

Negative pressure therapy was initially developed for problematic wounds, its use and advantages in fasciotomy wounds were however already described 20 years ago [9]. This method consists of filling the wound with open pore reticulated polyurethane foam, which is then covered by an adhesive tape and connected to the V.A.C. device to deliver negative pressure to the wound. It allows negative pressure to be equally distributed over the wound ground, whilst allowing secretions to be transported out of the wound into the V.A.C. device canister. Also, it seals the wound and so combines advantages of open and closed wound management [9, 10]. Despite its seemingly longer time to wound closure its growing popularity at our institution may be due to easier handling on the wards and a greater flexibility concerning the timing of dressing changes, as it can be changed as few as 1–2 times per week. V.A.C. dressings are associated with a lower infection rate, yet a longer time to wound closure would be a potential disadvantage [11]. Kakagia et al. prospectively compared the conventional wet dressings with shoelace technique to the V.A.C. device and found a statistically significant smaller number of days to wound closure and a slightly smaller rate of infection, as well as much lower costs in the shoelace group [12]. However, these results were obtained in an adult population and the comparison was made between the V.A.C. device and a form of dynamic closure, unlike our study. The tendency towards longer time to wound closure with the V.A.C. device may be due to its lack of direct means for contracting the wound in comparison to dynamic methods that have been shown to have shorter times to closure. A possible solution to this problem could be a combination of V.A.C. device with the traditional shoelace technique, which has so far only been described in adults [13–15].

Another potential disadvantage of the V.A.C. device is costs: at our clinic the material alone for one V.A.C. device dressing change would typically cost around 180 USD, compared to 20 USD for the Epigard[®] material.

Despite these supposed disadvantages the V.A.C. device could still be a valid treatment option in children, as the seemingly longer time to wound closure shown in our study may be due to a selection bias. We treat fasciotomy wounds either with SSR or a V.A.C. device, depending on the surgeon's preference and the intraoperative situation. Therefore, there may be a bias towards treating longer and more gaping wounds with a V.A.C. device, whereas smaller wounds could seem to be easily treated with SSR. A further confounding factor is that at our institution pediatric surgeons as well as pediatric orthopedic surgeons treat acute compartment syndrome, whereas the first tend to use SSR and the orthopedic surgeons are more likely to use a V.A.C. device. Another conceivable bias is due to the fact that a V.A.C. device can be left in place for a longer period of time without a dressing change amounting to possible longer time to wound closure compared to the SSR group. The retrospective design of our study, its small case number and the large heterogeneity of our patients are further limitations to the interpretation of our results.

In children, the clinical diagnosis of compartment syndrome is difficult, as the examination of a child in pain is very challenging, they are poor historians and bedside measurement of compartment pressure is not possible [16]. Furthermore, the normal values of the pediatric compartment pressure measurements of the lower leg are still unclear with as of yet only one published study on this topic [17]. We therefore strongly believe, especially in light of the above-mentioned results, that urgent fasciotomy should be performed in children even if in doubt of definite diagnosis. This holds true even if recent literature demonstrates a longer time until permanent muscle damage occurs in children [18] and a higher normal compartment pressure than the adult population [17, 19].

In conclusion, fasciotomy wounds in children have few complications so that urgent fasciotomy should not be postponed due to fear thereof. Both SSR and the V.A.C. device are safe and reliable for use in treating fasciotomy wounds after compartment syndrome of the lower leg in children. The possibly longer time to wound closure with V.A.C. device might be counteracted by combining it with the traditional shoelace method.

We plan to prospectively compare V.A.C. device with shoelace technique to SSR in the future.

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Compliance with ethical standards

Conflict of interest Hannah Rachel Bussell, Christoph Alexander Aufdenblatten, Corina Gruenenfelder, Stefan Altermatt and Sasha Job Tharakan hereby confirm that no conflicts of interest exist.

Informed consent The authors hereby confirm that informed consent is given by all patients involved in this study.

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