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Acute Compartment Syndrome of the Lower Leg: Retrospective Study on Prevalence, Technique, and Outcome of Fasciotomies

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Abstract. The acute compartment syndrome is caused by bleeding or edema in a closed muscle compartment surrounded by fascia and bone. It is characterized by increased intracompartmental pressure and decreased tissue perfusion. Well-known causative incidents are acute trauma and reperfusion after treatment for acute arterial obstruction. Most commonly the lower leg is involved. Inadequate therapy of the syndrome usually leads to muscle ischemia, rhabdomyolysis, and renal insufficiency. Perioperative morbidity and mortality are high. Although compartment syndromes can be caused by various factors, up until now no comparative studies have been published on clinical outcome of compartment syndromes of different origin. In this retrospective study we analyzed 40 successive cases of fasciotomy for acute lower leg compartment syndrome to study whether different causes of the syndrome lead to different clinical outcomes. We also studied other predictive factors for clinical outcome. The causes for the compartment syndromes were trauma, vascular deobstruction, cardiac surgery, and gastrointestinal surgery in lithotomy position. Clinical outcome showed a mortality of 15% and serious overall morbidity. Multivariate analysis showed the only significant predictive determinant of outcome to be the age of the patient. Fasciotomy for acute compartment syndrome is associated with serious morbidity and mortality. No correlation between causative factors and clinical outcome could be found.

The acute compartment syndrome of the lower leg is characterized by increased intracompartmental pressure and decreased tissue perfusion. Well-known causative factors are fracture, blunt trauma, and reperfusion after treatment for acute arterial obstruction. Compartment syndromes have developed also after excessive physical training, long-term surgery in the lithotomy position, and after use of an intra-aortic balloon pump [1–3]. Progressive edema or bleeding leads to increased intracompartmental pressure, diminished tissue perfusion with muscle ischemia, and subsequent necrosis. Rhabdomyolysis results in myoglobulinemia and subsequent renal insufficiency necessitating dialysis.

Clinical diagnosis is often not too difficult in conscious patients. The combination of a relevant trauma, a tight calf, and excessive pain sensation compared to the trauma should give rise to a high suspicion. A high serum creatine phosphokinase (CPK) and creatinine make the diagnosis likely. However, in unconscious patients the diagnosis is easily missed. A high index of suspicion in every patient at risk and frequent assessment of the calf are mandatory. Intracompartmental pressure measurement can be very helpful in establishing the diagnosis of compartment syndrome [4].

Despite claims of a positive effect of mannitol infusion therapy, treatment remains primarily surgery. All four compartments (anterior, lateral, deep posterior, and superficial posterior) need to be opened and decompressed, either via two separate incisions (one anterolateral and one posteromedial) or one lateral incision [5]. Some other authors describe a separate fifth compartment surrounding the tibial muscle, whereas others deny the existence of such a compartment [6, 7]. The subcutaneous technique, although successfully used in chronic compartment syndrome, appears to be insufficient in the acute compartment syndrome [8]. Especially in younger patients, an intact and firm skin could compress the leg like a tourniquet and consequently diminish the therapeutic effect of the fasciotomy. Therefore, the skin defect in open fasciotomy should not be closed primarily (in the same session it was opened). A temporary closure with synthetic skin substitute for the first 7 to 10 postoperative days, followed by delayed primary closure or delayed closure with split skin transplants is often performed. Also, Berman's Shoelace technique for secondary closure can be used successfully [9].

Adequate and timely treatment of the acute compartment syndrome can lead to healing with good functional and cosmetic results. However, results are not always good. After fasciotomy, mortality rates of 11%–15%, amputation rates of 11%–21%, and serious morbidity have been reported [10, 11]. If operative treatment is delayed or inadequate, excessive tissue necrosis may lead to amputation, renal insufficiency, and death [12].

Although compartment syndromes can be caused by a variety of factors, up until now no studies have been published on clinical outcome of compartment syndromes of different causes. Retrospective studies on clinical outcome after fasciotomy are scarce. Most authors describe either vascular or trauma-induced compartment syndromes. In this retrospective analysis we combined data of 40 successive cases of acute compartment syndrome of different causes to analyze clinical outcome in relation to their cause.

Materials and Methods

In the period August 1994 to August 2000, a total of 36 patients were treated for the clinical diagnosis of acute compartment syn-

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Table 1. Patient characteristics and causative factors of acute compartment syndrome.

	n	%	% Male	Mean age (years) of patients
Fracture	15	37.5	80	43
Blunt trauma	2	5.0	100	39
Elective arterial surgery	2	5.0	100	70
Acute arterial surgery	9	22.5	67	55
Cardiac surgery with extraorporeal circulation	5	12.5	80	61
Gastrointestinal surgery in lithotomy position	6	15.0	83	60
Other	1	2.5	100	26
Total	40	100	100	40

drome in the Department of Surgery of Maastricht University Hospital, The Netherlands. All of them underwent lower leg fasciotomies. Intracompartmental pressure measurement was seldom performed. Twenty-nine were men and seven were women. The average age was 52 years (range 19–91 years). Four of them (three men and one woman) developed a double-sided syndrome for which fasciotomies were performed in both legs, for a total of 40 limbs with a fasciotomy.

All records of these patients were analyzed for patient characteristics (sex, age, admission periods, and cause of the compartment syndrome), for therapy-associated data (technique of fasciotomy, number of opened compartments, prophylactic or therapeutic fasciotomy, and wound management), complications (significant wound infection, hematoma, nerve damage and postoperative pain), laboratory parameters (serum CPK and creatinine at the time of fasciotomy), and clinical outcome (death, amputation, leg dysfunction). Significant wound infection was defined as infection at the operation site necessitating antibiotic therapy or drainage. Hematoma was defined as bleeding or hematoma at the operation site necessitating transfusion or reexploration. Nerve damage was defined as motor nerve damage (mainly peroneal nerve lesion) or major sensible nerve damage. A "good" clinical outcome was defined as limb salvage with or without dysfunction, whereas a "poor" outcome was defined as amputation or death of the patient.

Statistical analysis was performed using SPSS 10.0 (SPSS, Inc., Chicago, IL). Correlation between patient characteristics and therapy-associated factors on the one hand and complications and outcome on the other hand were tested using χ^2 and univariate logistic regression analysis. Groups of patients were compared using a nonparametric Mann-Whitney rank test. Significant factors found after univariate analysis were further analyzed in multivariate logistic analysis to exclude confounders.

Results

The most common cause for acute compartment syndrome was trauma in 17 cases (fracture in 15 cases, blunt trauma in 2 cases), followed by arterial deobstruction or reconstruction in 11 cases. All causes of compartment syndromes are summarized in Table 1.

In 14 cases (35%), fasciotomy was performed "prophylactically," (which means in the same operative session as the causative operation or during primary fracture management) because of progressive swelling of the calf noted during operation. In the 26 other cases there was a mean interval between cause and fasciotomy of one day (range 0–9 days). In 32 cases (80%) all four compartments were opened, in 19 cases through an open single-incision technique; in 7, via an open two-incision technique. In the other six cases the technique used for the four compartment fasciotomy was not clearly defined. A subcutaneous technique was used in three cases. In five cases, technique and number of compartments opened were poorly defined.

Table 2. Skin wound management after fasciotomy.

	n	%
Direct primary skin closure	3	7.5
Direct closure with Epigard, followed by delayed primary closure (e.g., shoelace technique)	4	10
Direct closure with Epigard, followed by split skin graft	16	40
Open wound management, delayed primary closure (including the shoelace technique)	5	17.5
Open wound management, delayed closure with split skin graft	4	10.0
Poorly defined	8	20.0
Total	40	100.0

Skin wound management in 20 cases involved direct temporary closure with Epigard Synthetic Skin Substitute (The Clinipad Corporation, Norwich, CT 06360 USA), requiring definitive closure at a later stage. In the last period of the study Berman's Shoelace-technique for delayed primarily closure was introduced, with satisfactory results. The different types of skin wound management are summarized in Table 2.

Complications after fasciotomy were common. Nerve damage occurred in 6 cases (15%); bleeding was seen in 13 cases (35%). Wound infection occurred in 10 cases (25%). Functional outcome after fasciotomy was not always good. In this series 18 legs (45%) healed with good functional result, but in 11 cases (27.5%) the final outcome was a more or less disabled leg. In 5 cases, the fasciotomy could not prevent amputation of the affected limb and 6 patients died during the course of their hospitalization. None of the 4 patients who underwent double-sided fasciotomy died; nor did they undergo amputation. The outcome of all fasciotomies is summarized in Table 3. To compare our results with the existing literature, usually describing either only trauma induced or only vascular induced compartment syndromes, we analyzed separately our vascular-induced injuries (fasciotomies after acute and elective arterial surgery) and our trauma-induced injuries (fasciotomies for fractures and blunt trauma) fasciotomies. The two groups differed remarkably. The subpopulation with vascular injuries was older (average age 58 versus 42 years) and had a significantly worse outcome. Results are shown in Table 4.

Determinants of outcome after fasciotomy were analyzed using univariate logistic regression. A "good" outcome was defined as limb salvage with or without dysfunction. A "poor" outcome was defined as amputation or death of the patient. Age appeared to be an important determinant for outcome. Patients under 60 years of age had a better outcome than the older patients ($p = 0.010$). A serum creatinine of over 120 μmol/l (normal 53–110 μmol/l) at the time of fasciotomy was a predictor of poor outcome ($p = 0.026$). The fasciotomy technique used did not show a significant correlation with outcome. The outcome after fasciotomy in case of fracture was significantly better than the overall outcome in this series. Patients with an acute arterial occlusion showed the worst outcome

Table 3. Outcome of all fasciotomies.

	n	%
Death of the patient	6	15.0
Amputation within 30 days	2	5.0
Amputation after 30 days but within 1 year	3	7.5
Dysfunctional limb	11	27.5
Limb with good function	18	45.0
Total	40	100

Table 4. Outcome after fasciotomy, divided by subgroup.

	Vascular ($n = 11$)	Trauma ($n = 17$)	*p*
Mean age (years)	58	42	0.050
Death	4 (36%)	1 (6%)	0.040
Amputation	2 (18%)	0 (0%)	NS
Dysfunctional leg	4 (36%)	6 (35%)	NS
Functional leg	1 (9%)	10 (59%)	0.008
"Good" outcome	5 (45%)	1 (6%)	0.004
Mean highest creatinine (mmol/l)	165	110	0.033
Mean highest CPK (mmol/l)	21,529	2953	NS

CPK: creatine phosphokinase.

Table 5. Analysis of predictors of good outcome.

	Odds ratio	95% CI	Conclusion
Age > 60	0.01	0.00–0.12	Worse outcome
Male sex	3.57	0.71–18.04	NS
Prophylactic operation	8.12	0.92–72.00	NS
Four compartments opened	0.32	0.03–2.91	NS
Nerve damage	0.72	0.11–4.63	NS
Hematoma	0.46	0.11–1.93	NS
Wound infection	4.50	0.50–40.65	NS
Serum creatinine > 120	0.16	0.03–0.89	Worse outcome
Serum CPK > 6000	0.41	0.09–1.78	NS
Caused by fracture	9.33	1.05–82.60	Better outcome
Caused by acute arterial obstruction	0.19	0.04–0.94	Worse outcome
Caused by elective arterial surgery	0.36	0.02–6.26	NS
Caused by cardiac surgery	0.20	0.03–1.40	NS
Caused by gastrointestinal surgery	2.08	0.22–20.17	NS

after fasciotomy. These and other determinants of outcome are listed in Table 5.

The effects of age and causative factor on outcome are graphically shown in Figure 1 and 2.

We also investigated determinants for complications using a χ^2 test. Age, sex, cause of the compartment syndrome, and technique of fasciotomy did not predict hematoma. Nerve damage was seen more commonly after the open single-incision technique than after fasciotomy using the other techniques ($p = 0.046$). Other factors did not predict nerve damage. Wound infections were more common after elective arterial occlusion than after other causes ($p = 0.012$). The skin wound management technique did not show a significant correlation with wound infection. A multivariate logistic regression analysis was done to check whether statistically significant predictors of outcome found with univariate logistic regression remained significant if combined. To identify accidental confounders, the following factors were analyzed: age, creatinine, acute arterial obstruction, and fracture. Only age greater than 50 years remained a significant predictor of poor outcome ($p = 0.000$). The other determinants lost significance in multivariate analysis and were therefore excluded.

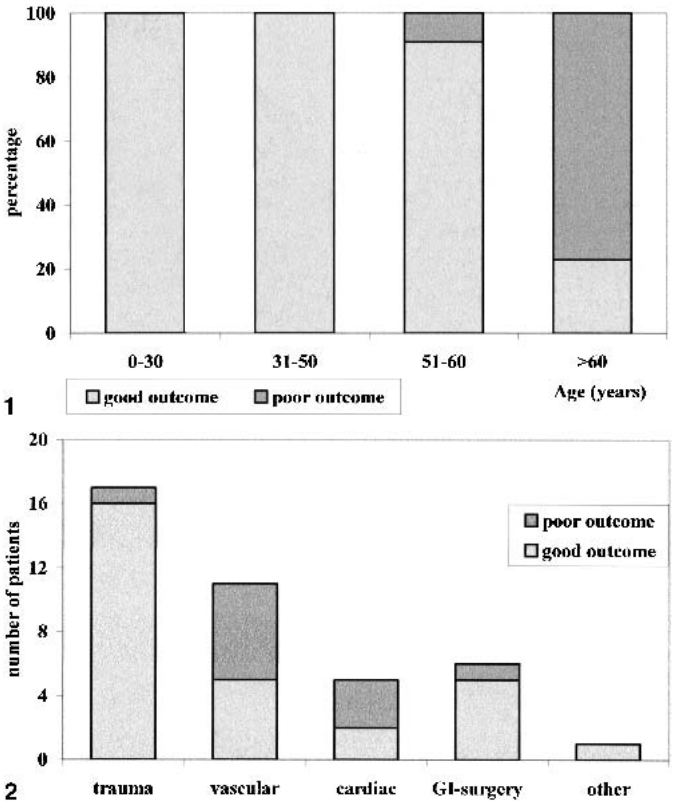

Fig. 1. Relationship between age and clinical outcome in 40 cases of compartment syndrome.

Fig. 2. Relationship between cause of the compartment syndrome and clinical outcome in 40 cases. GI: gastrointestinal.

Discussion

The cause of the compartment syndrome appeared to be an important predictive factor for outcome. Post traumatic compartment syndromes had a better outcome after fasciotomy than vascular injuries. However, the mean age of the fasciotomy patients after trauma was 16 years below that of the vascular fasciotomy patients. They also had a lower serum CPK and a lower serum creatinine than the others. Because younger age was the only predictive factor for a relatively better outcome in a multivariate logistic regression analysis, we cannot exclude the possibility that serum creatinine and trauma were causative factors of the compartment syndrome and are just confounders and of no predictive value.

Although the compartment syndrome is generally thought of primarily as either a vascular problem or a result of trauma, no less then 30% of cases in our research population developed compartment syndrome after surgery in other fields of medicine, including oncologic surgery, gastrointestinal surgery, cardiac surgery, and orthopedic surgery. This finding illustrates the importance of diagnosis and treatment of the compartment syndrome in all territories of surgery.

We were not able to identify any relationship between the severity of the compartment syndrome, its treatment, and its clinical out-

come. It is likely that intracompartmental pressure measurements could have given an indication in assessing the severity of the compartment syndrome; however, pressure measurement was not deemed necessary in all patients in our series. In the majority of cases, diagnosis was established mainly or solely by the clinical symptoms of pain, a tight calf, and relevant trauma. Therefore, no reliable parameter is available to assess severity of the compartment syndrome.

The extent and severity of the clinical syndrome probably influences the choice of treatment. A more extensive and severe compartment syndrome might be operated upon earlier and more aggressively, opening all four compartments, whereas a mild clinical syndrome might result in late and less invasive surgical treatment. At discharge, 45% of our patients had good limb function, 27.5% had kept their leg with diminished function, 12.5% underwent amputation, and 15% died. These results are comparable with reported earlier studies by Rush et al. [10] in 1989 and Jensen and Sandermann [11] in 1997, showing 11% to 15% mortality and 11% to 21% amputation. However, both studies only included patients after vascular surgery (over 95% after acute arterial occlusion), a subgroup with relatively poor postoperative outcome. If we compare these studies with our vascular subpopulation, showing a mortality of 36% and an amputation rate of 18%, we find equally poor or even worse results after fasciotomy.

Although previous studies clearly show the importance of early operative intervention, we could not find a correlation between prophylactic versus therapeutic treatment and clinical outcome, or between interval delay in fasciotomy and clinical outcome [12]. It is likely that more predictors of clinical outcome could have been identified if our research population had been larger.

Conclusions

The acute compartment syndrome is potentially life-threatening and limb-threatening, associated with a mortality of rate of 15% and serious morbidity. Results have remained invariably poor over the past decade. Posttraumatic compartment syndrome patients had a better outcome after fasciotomy compared to vascular fasciotomy patients. However, in a multivariate logistic regression analysis, younger age was the only predictive factor for a relatively good outcome. Although often thought of as mainly a vascular or traumatologic problem, a significant number of patients came from other surgical disciplines (gastrointestinal surgery, cardiac surgery) making knowledge of diagnosis and treatment of the compartment syndrome important in all fields of surgery.

Résumé. Le syndrome de compartiment aigu est en rapport avec une hémorragie ou de l'oedème dans un compartiment musculaire fermé entouré d'aponévrose et de l'os. Il est caractérisé par une augmentation de pression intra-compartimentale et une diminution de la perfusion tissulaire. Les causes les plus connues sont le traumatisme aigu et la reperfusion après traitement d'occlusion artérielle aiguë. Le plus souvent, il s'agit du membre inférieur. Une thérapie inadaptée du syndrome amène vers l'ischémie musculaire, la rhabdomyolyse et une insuffisance rénale. La morbidité et la mortalité périopératoires sont élevées. Bien que le syndrome compartimental puisse être en rapport avec divers facteurs, jusqu'à présent, aucune étude comparative n'a été publiée concernant l'évolution clinique des différentes origines. Dans cette étude rétrospective, nous avons analysé 40 cas successifs d'aponévrotomie afin d'étudier si les causes différentes de syndrome de compartiment du membre inférieur sont associées avec une évolution clinique différente. Nous avons aussi étudié d'autres facteurs prédictifs de l'évolution clinique. Les causes du syndrome de compartiment aigu ont été le trauma, la désobstruction vasculaire, la chirurgie cardiaque et la chirurgie gastro-intestinal en position de lithotomie. L'évolution clinique fait état d'une mortalité de 15% et une morbidité globale sévère. L'analyse multivariée a montré que le seul facteur prédictif de l'évolution a été l'âge. L'aponévrotomie d'un syndrome de compartiment aigu est associée à une morbidité et une mortalité sévères. On n'a retrouvé aucune corrélation entre les facteurs étiologiques et l'évolution clinique.

Resumen. El síndrome compartimental agudo de las extremidades se debe a un incremento de la presión intracompartimental producida por una hemorragia o edema en un compartimento muscular limitado por fascias y hueso. El incremento de la presión determina una disminución de la perfusión textural. La etiología más frecuente se refiere a traumatismos agudos o al síndrome de reperfusión tras el tratamiento satisfactorio de una obstrucción arterial aguda. Es más frecuente en miembros inferiores. Un tratamiento inadecuado del síndrome origina una isquemia muscular, una rabdomiolisis y una insuficiencia renal. La morbi-mortalidad perioperatoria es alta. Aunque el síndrome compartimental puede ser debido a diferentes factores etiológicos, hasta la actualidad no se han realizados estudios comparativos de los resultados obtenidos en el tratamiento de síndromes compartimentales de diferentes etiologías. En este estudio retrospectivo analizamos 40 casos de fasciotomía realizadas por síndrome compartimental agudo de miembros inferiores, estudiando sí las diferentes etiologías del síndrome propician resultados clínicos distintos. También consideramos otros factores predictivos que influyen en los resultados clínicos. La etiología de los síndromes compartimentales fueron: traumatismos, desobliteración vascular, cirugía cardiaca y cirugía gastrointestinal en posición de litotomía. Los resultados clínicos muestran una mortalidad del 15% y una morbilidad global elevada. Los análisis multivariantes demuestran que la edad es el único factor predictivo determinante de los resultados clínicos. La fasciotomía como tratamiento de síndrome compartimental agudo se acompaña de importante morbi-mortalidad. No existe correlación alguna entre las causas etiológicas y los resultados clínicos.

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