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ORIGINAL STUDY

Is acute compartment syndrome avoidable ?

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Complete absence of acute compartment syndrome was observed in a consecutive series of 966 tibial fractures in African patients of diverse ethnic groups, reviewed retrospectively at our institution. Considering the incidences reported in the literature, we should have experienced between 22 and 86 cases of acute compartment syndrome. The purpose of this prospective study was to confirm these findings and at the same time to look for possible explanations for this unexpected observation.

During a period of one year and four months, 257 tibial fractures were prospectively analyzed for clinical signs and late sequelae of acute compartment syndrome. In 156 of these patients, presenting 158 fractures of the tibia, the pressure in the anterior compartment was systematically measured. No single case of compartment syndrome was diagnosed in this series, and no late sequelae of acute compartment syndrome were noted.

The hypothesis we forward for total absence of acute compartment syndrome is the favourable effect of the continuously high surrounding temperatures on safeguarding the arteriovenous pressure gradient and lowering the vascular resistance. We suggest that further investigation should be carried out to study this hypothesis.

INTRODUCTION

Various conditions may lead to acute compartment syndrome (ACS) in different anatomic locations, such as fractures, blunt trauma, exercise or tumours. Acute compartment syndrome, however, is mainly a most dreaded complication of tibial fractures, in which it occurs with a frequency ranging from 2.4% to 9% (*1, 3, 4, 5, 10, 13, 15, 16, 17*). In a retrospective study of 966 fractures of the tibial diaphysis, comprising 251 open fractures treated at our institution over a period of 6 years, not one single case was complicated by ACS. Failed diagnosis could not be ruled out in this retrospective review, but even so we should at least have been confronted with late sequelae of ACS.

As we were aware of the poor scientific value of this clinical observation, a prospective study of tibial fractures was undertaken.

MATERIALS AND METHODS

During a period of 16 months, 262 patients were admitted with a diaphyseal fracture of the tibia in the trauma department at the National University Hospital of Niamey in Niger, West-Africa, which is the reference hospital for the whole country. Fifty-two patients also presented other fractures and 9 patients had a cranial trauma. Three patients died from these injuries. Five patients chose for treatment by traditional healers. Two patients underwent an emergency amputation because of

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untreatable damage. The remaining 252 patients underwent treatment for 257 diaphyseal fractures of the tibia. A diaphyseal fracture of the tibia was defined according to the criteria of Müller *et al*, and extra-articular fractures in the proximal and distal 5 cm were excluded (*18*).

One hundred and ninety two fractures were treated non-operatively and 65 fractures underwent surgical treatment. Non-operative treatment of the tibial fractures uniformly consisted of closed reduction followed by immobilization in a posterior plaster of Paris splint, supplemented if necessary by a U-splint. A circular cast was applied ten days later.

In each patient the clinical signs of ACS (*7, 20, 21*) (severe pain, painful passive movement, sensory deficit, motor deficit) were systematically recorded during the 48 hours following trauma or operation. All patients were followed during at least 3 months (mean 6 months, range 3 to 11 months), paying special attention to signs of sequelae of a possible missed diagnosis of ACS, such as muscle weakness or muscle contractures. Throughout follow-up we lost sight of two patients.

In a non-selected subgroup of 158 fractures (156 patients), the pressure in the anterior compartment was measured.

As the anterior compartment is constantly involved in ACS (*15*), the pressure was systematically measured by needle puncture in the anterior compartment only, according to the method described by Whitesides (*24*), within 5 cm of the fracture site for reasons of reliability of pressure measurement, as it has been shown that the pressure is significantly more elevated within a range of 5 cm from the fracture site than in a more remote location (*10*). The same physician executed all measurements, and these were performed according to his availability. The measurements after operative procedure were systematically carried out within 3 hours following operation. The differential pressure (ΔP) between the diastolic blood pressure and the compartment pressure was calculated, according to Whitesides and McQueen, and we adopted the definition of critical ACS requiring fasciotomy, when the ΔP was less than 30 mmHg (*3, 15, 16, 23*).

Statistical analysis used the chi-squared test.

No statistically significant difference ($p < 0.05$) existed regarding gender, age, cause of injury, type of fracture and type of treatment, between the group of fractures in which pressure measurements were not done and those in which the measurements were performed (table I).

In total 185 measurements were performed : 137 measurements in 137 different patients during the 48 hours following trauma and 48 measurements postoperatively in patients whose fractures were surgically treated. Twenty-seven patients underwent a measurement both after trauma and after operation.

Table I. — Causes of injury in the 156 patients in whom the pressure in the anterior compartment was measured

	Number
Road traffic accident	127
Fall	14
Assault	8
Sport	7

Table II. — Type of tibial fractures in the group measured after trauma according to the AO-ASIF and Gustilo classifications

	Number	Percentage
AO-classification		
42 - A	61	45
B	41	30
C	35	25
Gustilo (open injuries)		
I	21	40
II	12	23
III	20	37
IIIa	14	70
IIIb	6	30
IIIc	0	0

Details are given in table II regarding the fracture types in the group measured after trauma, both according to the AO classification (*18*) and the Gustilo classification for open fractures (*9*).

As there is a good correlation between the basic AO classification and the Tscherne classification, we considered that all fractures classified as type C resulted from high-energy trauma (*2*).

RESULTS

No single patient out of the 252 in the study developed symptoms of ACS during the 48 hours following trauma or operation. Two hundred and fifty patients (99%) could be followed during 3 months and sequelae of ACS were seen in no instance.

In 17 of the 185 measurements performed after trauma or after surgery, the ΔP was below 30 mmHg (9%).

Table III. — Operative procedure and corresponding frequency of measurements showing ΔP < 30 mm Hg

Procedure	Number	ΔP < 30
External Fixator	33	3
Nailing	3	0
Plating	12	0

Table IV. — Delay of measurement and corresponding frequency of measurements showing ΔP < 30 mm Hg

Delay	Measurements	ΔP < 30	
		Number	Percentage
< 6 hours	38	9	23%
6 – 12 h	55	3	5%
12 – 24 h	28	1	4%
24 – 48 h	16	1	7%
Total	137	14	

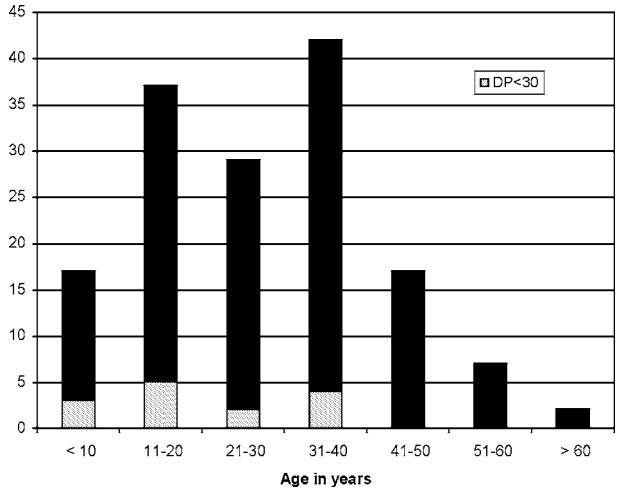

Fig. 1. — All patients presenting ΔP < 30 mmHg were younger than 40 years.

Among the measurements made after surgery, there were 3 cases with a ΔP < 30 mmHg, all in the external fixation group (table III).

The measurements performed in the first 6 hours after trauma showed a higher prevalence of ΔP < 30 mmHg than those carried out later (table IV). The frequency of measurements showing ΔP < 30 mmHg was significantly higher among measurements performed within 6 hours after injury than among those carried out after 6 hours ($p < 0.001$).

Among the measurements performed after trauma, there were 6 showing ΔP < 30 mmHg (17%), which were all found in the 35 high-energy type C fractures, and 8 (8%) in the 102 low-energy type fractures ; there were 6 measurements showing ΔP < 30 mmHg (11%) in the 53 open fractures, and 8 showing ΔP < 30 mmHg in the 84 closed fractures (9%) ; all measurements showing ΔP < 30 mmHg were in patients younger than 40 (fig 1).

DISCUSSION

Taking the incidence of ACS reported in other series as a reference (*1, 4, 5, 13, 15, 16, 17*), we should have experienced between 6 and 23 cases of ACS in the 257 tibial fractures (252 patients) in this study group. Nevertheless not a single case of ACS was clinically diagnosed. This complete absence of ACS and of any late sequelae of ACS in this prospective study, confirms our initial finding, which was based on a retrospective review of 966 fractures of the tibial diaphysis.

In an unselected subgroup of 156 patients, which was structurally representative for the whole tibial fracture group, we have demonstrated that the intracompartmental pressure rose above the universally acknowledged critical value that triggers ACS, in a similar proportion as reported in other populations (*1, 4, 13, 15, 16, 17*) but failed to further develop into a clinical ACS .

Continuous monitoring was not available at the time of the study, and we are aware that with the technique we used, a complete picture of the evolution of the pressure fluctuations could not be obtained and that the readings could have turned out less accurate than with other methods (*19*).

All instances of ΔP < 30mmHg but one, occurred during the first 24 hours following injury, with a higher incidence in the first 6 hours and in patients younger than 40. McQueen *et al* found a higher incidence of ΔP < 30 mmHg during the second 12-hour period after trauma and mainly in patients younger than 35 (*15, 16*).

Like other authors (*16, 17, 22*), we found more ΔP < 30mmHg values in high-energy injuries and a

similar incidence of $\Delta P < 30$ mmHg in open and closed fractures.

The incidence of both type C fractures and open fractures is higher in this series than in the epidemiological study carried out in Edinburgh, where an incidence of 18.3% was found for type C fractures, and 23.5% for open fractures (*2*).

Twenty-three of these open fractures were admitted after a delay of more than 6 hours, increasing the complexity of the therapeutic approach (*12*). Eighty four percent had been injured in road traffic accidents, which is in correlation with the distribution of global causes of injuries in Niamey (*11*).

When measured after surgery, all $\Delta P < 30$ mmHg concerned external fixation, but the number of surgical procedures is too low to allow for any conclusions. An explanation could be that all the external fixators were applied during the first hours following trauma, whereas internal fixation by plates or nails was carried out with a delay of more than 48 hours, allowing oedema to recede.

ACS is caused by an elevation of intracompartmental pressure. The result is not a vascular occlusion, but a decrease of the local arteriovenous gradient entailing a diminution of local tissue perfusion, and ischaemia. The capillary endothelium will suffer damage and allow transsudation of fluid into the interstitial space, giving rise to an increase in the content of the compartment until local blood flow is unable to meet the metabolic demands of the tissue. Muscle and nerve ischaemia will occur, leading to possibly irreversible damage to the contents of the compartment (*8, 14, 17, 25*).

An explanation for this perplexing total absence of clinical ACS could not be forwarded by this study. We can only elaborate hypotheses.

A common trait, such as a higher elasticity of the teguments or a better tolerance of the muscle tissue to ischaemia (*22*), in this study population is hardly plausible, as this population is genetically very heterogeneous. We are not aware of any mention of racial factors concerning ACS in the medical literature. The fact that in the conservatively treated patients, we never applied a circular closed cast in the first days following injury, but rather an open plaster splint, could have lowered the incidence of ACS, but not make it vanish (*6*).

In the study region the ambient temperature is always fairly high all year around, compared to other parts of the world. The outside temperature never reaches values below 20°C, and the inside temperature goes exceptionally below 25°C, with air conditioning almost nonexistent in the hospital wards. Under these circumstances, another explanation could be that these chronically high temperatures maintain the arteriovenous gradient and lower the vascular resistance (*14*).

Warming up the injured limb to avoid occurrence of ACS could thus be the positive answer to the question in the title of this article.

Further investigations have to be performed to confirm this hypothesis.

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