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PERFUSION PRESSURE AS A DETERMINANT OF THE NEED OF FASCIOTOMY IN ACUTE COMPARTMENT SYNDROME OF THE EXTREMITIES

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ABSTRACT

Background

Compartment syndrome is a clinical state of increased tissue pressure within a closed space resulting in compromised local circulation and subsequent dysfunction of the enclosed myoneural elements. Delay in diagnosis and treatment for several hours may result in permanent disability. Intracompartmental pressure monitoring would identify the patients who would benefit by early fasciotomy and prevent grave complications.

Material and Methods

144 limbs were studied (72 affected and 72 control). Intracompartmental pressure and perfusion pressure were measured by indigenous saline infusion device.

Results

Perfusion pressure <13 mm Hg in patients of electric burn arriving as early as 6 hrs required amputation. Patients with multiple fractures of the lower limb who arrived within 8-20 hours with perfusion pressure <22 mm Hg were managed by early fasciotomy but later landed in amputation. Patients having perfusion pressure >50 mm Hg with no neural deficit were conserved. When the compartment pressures rose beyond 45 mm Hg and perfusion pressure fell below 25 mm Hg with partial or no neural deficit, fasciotomy was indicated and performed in 51 patients. All patients improved clinically and the decrease in compartment pressure was 45% to 60%.

Conclusions

Intracompartment pressure monitoring serves as a guideline to decide between conservative management and fasciotomy. Perfusion pressure <25mm Hg is a definite indication for fasciotomy. Ignorance may lead to ampuations, paresthesias and later on Volkmann's Ischaemic Contracture.

KEYWORDS: Compartment Syndrome, Fasciotomy, Intracompartmental Pressure Measurement, Perfusion Pressure

INTRODUCTION

Compartment syndrome is a condition in which the perfusion pressure falls below the tissue pressure in a closed anatomic space with subsequent compromise of circulation and function of tissues. As many as 45% of cases are caused by tibial fractures. Other causes include reperfusion following vascular injury, crush injury, burns, drug overdose [1] and a tight cast or dressing. The compartment syndrome is rather uncommon in the experience of a practitioner.Therefore, he may be unfamiliar with its diagnosis and management which, at times, may be serious and disastrous.The clinical diagnosis of compartment syndrome is rather difficult because certain other conditions may mimic symptoms and signs. In the 1970s, the importance of measuring compartmentpressurewas emphasised upon.

Perfusion pressure is the difference of diastolic blood pressure and compartment pressure. A prospective study was initiated with the aim of evaluation of perfusion pressure in patients with acute compartment syndrome and identifying the subset of patients who would benefit from early fasciotomy.

MATERIAL AND METHODS

The patients at risk to develop acute compartment syndrome of the upper and lower extremities attending Plastic surgery, Orthopaedics and Surgery departments were included in the study. A total of 144 limbs in 72 patients were studied. The other limb was used as control. A detailed history was elicited and thorough clinical examination was carried out. Grossly or minimally swollen extremities were important inclusion criteria.

Compartment pressure and diastolic blood pressure were measured. Hence perfusion pressure, as the difference of the a fore mentioned parameters, was calculated and evaluated. These parameters helped to assess the need of early fasciotomy. Neurovascular deficit was an important factor which was carefully evaluated.

Apart from the general information, certain specific information regarding the compartment syndrome were noted (Table 1).

The technique to measure compartment pressure required the following equipments

- 18 gauge needle
- 10mL syringe
- Intravenous extension tubing (two)
- Vial bacteriostatic normal saline
- Aneroid manometer
- Three-way stopcock (Figure 1)

The three-way stopcock is a stopcock that communicates with three ports simultaneously (Figure 2). The stopcocks have a single lever which always points to the port that is off. In normal use, the stopcock lever can be placed in any position between 9, 12 and 3 o'clock. In these positions, the stopcock communicates with two ports at a time, with one port off. However, in the 6 o'clock position, the stopcock communicates with all three ports simultaneously.

The site of needle insertion in the closed compartment was cleaned with a povidone-iodine solution. Intravenous extension tubing to the front and rear ports of the three-way stopcock were connected (Figure 3). The 10ml syringe, with the plunger at the 3ml mark was connected to the upper port. The sterile 18-gauge needle was connected to the end of the IV extension tubing. Then the stopcock was turned to 3 o’clock so that the other IV extension tubing is off. The needle was put into a bottle of bacteriostatic saline to draw up some saline through this needle so that saline fills the tubing from the tip of the needle to a halfway point in the tubing. The other half of the tubing (nearest to the stopcock) and the syringe contained only air. The IV extension tubing (from the 3 o'clock port) was attached to the aneroid manometer. The needle was inserted into the designated muscle compartment to a depth of 1-3 cm depending on the thickness of the subcutaneous fat. Care taken not to enter the tendons The stopcock lever was turned to the 6 o'clock position so that all three ports are open simultaneously. The plunger was depressed slowly causing a rise in the pressure within the system. The arrow in the aneroid manometer rose until the pressure within the system was equivalent to the pressure within the compartment. As the pressure within the system exceeded the pressure in the compartment, the saline in the connection tubing slowly moved towards the needle. The reading on the manometer at the time that the saline first begins to move represented the compartment pressure. In the upper limb pressure was measured in the anterior compartment. In the lower limb, it was measured in the anterior and posterior compartment. Fasciotomy in forearm was done by a longitudinal ulnar incision. The superficial and deep posterior compartments were decompressed through a medial longitudinal incision placed 1-2 cm posterior to the medial border of the tibia. A second longitudinal incision 2 cm lateral to the anterior tibial border decompressed the anterior and peroneal compartments.

Electrophysiological studies were done on a 4 channel EMG machine. The motor and sensory conduction of the affected limb and the contralateral limb(control) were studied. The sensory conduction across the wrist was evaluated by orthodromic stimulation of digital nerves.

The motor conduction velocity and the distal latency of the peripheral nerves were measured by varying the positions of recording and reference electrodes.

All data were statistically analysed. Mean, standard deviation, correlation co-efficient were calculated. The z-test was used wherever applicable. In the z-test z values were calculated and the corresponding p-values were noted down from the table of Unit Normal Distribution. p-value< 0.001 was considered significant.

RESULTS

144 limbs (72 affected and 72 control) were studied. The mean age of the patients was 23.3 years (range 4 – 40 years), 77.8%being males. The major cause of compartment syndrome was automobile accidents (47.2%) (Table 2). 28 out of 36 patients (77.8%) diagnosed as compartment syndrome of lower extremities were due to high velocity trauma. 6 out of 36 patients (16.7%) with compartment syndrome of upper limb were due to road traffic accidents, the main cause was burns (38.9%). 38.7 hours (5-240) elapsed following injury before patients could arrive in emegency.

Average compartment pressure in the affected limb as measured by the device was 38.7 ± 12.2 mm Hg, and that in the control was3.5 ± 1.8 mm Hg. Perfusion pressure was 30.6 ± 13.8 mm Hg. Patients who arrived within 6 hours of injuryalso had very high compartment pressure (47.2 ± 11.8 mm Hg) and very low perfusion pressure (24.4 ±16.1 mm Hg) (Table 3).

In patients with perfusion pressure low as 33 mm Hg peripheral pulses became feeble and then gradually disappeared. The probable reason may be massive edema of the limb and consequentially decreased palpability of the pulses. The diagnostic symptoms and signs of pain on passive stretch and pain out of proportion to the injury was also present in these patients.

Complete to near complete motor and sensory deficit was present in patients with *compartment pressure ≥45 mm Hg and perfusion pressure ≤ 20 mm Hg.* This varied from patient to patient. This variability in pressure tolerance may be due to lack of concensus regarding *"critical pressure"* that mayassist in diagnosis and treatment of compartmental syndrome.

In our study, compartment pressure of ≥45 mm Hg or a perfusion pressure of ≤ 25 mm Hg resulted in rise of local temperature and tense limb (evidence for increased tissue pressure), complete loss of motor and sensory function (evidence for loss of tissue function) and pain on passive stretch and pain out of proportion to the injury (evidence for inadequate perfusion of local tissue) (Table 4).

In the upper limb, sensory and motor conduction velocity could not be recorded in patients with compartment pressure of ≥ 47.6 mm Hg (≥ 38 mm Hg in lower limb) and perfusion pressure of ≤ 19.6 mm Hg. Neither motor nor sensory nerve conduction could be recorded at lower perfusion presuure. Longer periods of persistently high compartment pressure produced more frequent functional losses.

Pre-management and post-management measurements established the need for urgent fasciotomy when the perfusion pressure falls below 25mm Hg.

DISCUSSIONS

In compartment syndrome, increased tissue pressure compromises local circulation to the point where the tissue's metabolic needs are no longer met and functional abnormalities ensue. The fact that increased tissue pressure compromised local circulation was demonstrated by the plethysmographic studies[2]. These studies indicated that perfusion pressure lower than 20 mm Hg significantly reduced local blood flow. Several confounding theories were proposed to explain development of compartment syndrome at high tissue pressure such as arterial spasm producing intracompartmental ischemia, microvascular occlusion[3] and reduction of the local arteriovenous gradient and thereby local blood flow [4]. Irrespective of the theory, early identification of compartment syndrome remains paramount to prevent amputations as also permanent paresthesia and Volkmann's ischaemic contracture in long standing cases.

Some authors suggested fasciotomyfor compartment pressure of 30 mm Hg. This was because this pressure sustained for 6-8 hours resulted in irreversible damage [5]. However, others argued that compartment pressure should be related to the systemic diastolic pressure to determine the critical pressure. The issue of this critical pressure was studied by Whitesides et al. He carried out experimental and clinical technique of measuring tissue pressures within closed compartments and demonstrated inadequate perfusion and relative ischemia when the tissue pressure within a closed compartment rose to within 10-30 mm Hg of the patient's diastolic blood pressure. Fasciotomy was usually indicated in this setting[6]. Yet another study proposed fasciotomy at 30 mmHg[7]. Increased tissue pressure also compromised neuromuscular function. In rabbits pressure of 40 mm Hg for six hours demonstrated a loss of response to the electrical stimulus, pressure of 60 mm Hg for six hours produced more consistent functional losses and pressure of 100 mm Hg for 8 or 12 hours produced loss of all discernible response to nerve or muscle stimulation[8].

We found that fasciotomy was necessary in patients with perfusion pressure <13 mm Hg, failing which amputation was required. Such a situation arose in patients who sustained electric burn of the upper limb (Figure 4). Therefore, it is strongly emphasized that patients with extensive electric burn of the limbs should be managed by urgent fasciotomy and to conserve every single bit of tissue.

Prophylactic double-incision fasciotomy prevents progression of soft tissue injury in high-energy trauma [9]. Fractures of the lower limb who arrived within 8-20 hours with perfusion pressure <22 mm Hg were managed by early fasciotomy (Figure 5). However they also later landed up in amputation. It can be suggested that patients with perfusion pressure <20 mm Hg have poor chances of limb survival especially when they arrive late(Table 5).

Classic symptoms of pain out of proportion and pain on passive stretch were observed in almost all patients except in 2 patients. They had perfusion pressure above 65 mm Hg. Patients having perfusion pressure >50 mm Hg and no neural deficit were conserved and no fasciotomy was performed.. The pressures gradually improved (Table 5). When the perfusion pressure fell below 25 mm Hg partial or complete neural deficit became more prominent. Fasciotomy was indicated and patients improved clinically. The decrease in compartment pressure was 45% to 60%.

Motor and sensory loss were observed in patients having compartment pressures >45 mm Hg and perfusion pressure <25 mm Hg especially when patients the presented as late as 28 hours. It was also observed that nerve conduction was not recordable in patients with compartment pressures >47 mm Hg and perfusion pressure <19 mm Hg. Clinically, these patients had loss of motor and sensory function. Findings were more consistent in the lower limb. We conclude that clinical findings correlated most of the times with electrophysiological studies and, therefore, a thorough clinical examination would eliminate the need of more expensive and cumbersome electrophysiological studies.

CONCLUSIONS

Intracompartment pressure monitoring serves as a guideline to decide between conservative management and fasciotomy. All patients with extremity compartment syndrome should undergo urgent fasciotomy if perfusion pressure falls **below 25 mm Hg**. Ignorance may lead to ampuations, paresthesias and Volkmann's Ischaemic Contracture.

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Conflict of Interest

The author declares that he does not have any conflict of interest

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APPENDICIES

Table 1: Specific Information and Examination Findings in Patients with Compartment Syndrome

Blood pressure	Pulse
Colour of urine	Redness
Local temperature	Site of injury
Motor and sensory status	Swelling
Nature of injury	Tenderness
Pain on passive stretching	Time since injury
Pain out of proportion to the injury	Urine output
Peripheral pulses	

Table 2: Distribution of Patients According to Etiology

Etiology	No. of Patients	Percentage	Upper Limb	Average CP (in mm Hg)	Lower Limb	Average CP (in mm Hg)
Road TrafficAccidents	34	47.2	6	26.67	28	41
Burns	14	19.4	14	41.43	0	0
Fall FromHeight	10	13.9	8	41.5	2	40
Postoperative	6	8.3	2	56	4	27.25
Post POP/cast	6	8.3	4	40.75	2	36
Gunshot	2	2.8	2	28	0	0

Table 3: Average Compartment and Perfusion Pressure in Relation to the Time Elapsed following Trauma when Patients Arrived

Duration	No. of Patients	Average CP (mm Hg) ± SD	Average PP (mm Hg) ± SD
<6 hrs	9	47.2 ± 11.8	24.4 ±16.1
6-24 hrs	35	38.8 ±10.6	30.6 ± 14
24-72 hrs	18	34.2 ± 15.3	36.4 ± 11.8
>72 hrs	10	36 ± 10.9	26 ± 14
		r = - 0.044	**r = - 0.073**

Table 4: Clinical Findings and Correlation with Perfusion Pressure

	Absent Motor and Sensory Functions +Raised Local Temperature +Pain Out of Proportion to the Injury +Pain on Passive Stretching (n = 72)
Duration	28.4 hours
Average compartment pressure	43.6 ± 7.4 mm Hg
Average perfusion pressure	24.2 ± 11.9 mm Hg
Fasciotomy in	55 patients
Conservative in	13 patients (1later on required amputation)

Table 5: Pre- and Post- Management Measurements in Patients with Compartment Syndrome of the Extremities

Procedure	No. of Patients	Pre-Op		Post-Op	
		Average CP ± SD mm Hg	Average PP ± SD mm Hg	Average CP ± SD mm Hg	Average PP ± SD mm Hg
Conservative	13	28.57 ± 9.14	50.33 ± 7.98	13.71 ± 8.19	56 ± 16.12
Fasciotomy	51	42.2 ± 9.83	23.2 ± 8.14	17.2 ± 8.76	56.8 ± 13.27
Amputation	4	56.5 ± 20.87	13 ± 4.30		
Later on amputation	4	49.5 ± 9.14	22.3 ± 17.04	40.5 ± 10.24	31.5 ± 11.23

Figure legends

Figure 1: Compartment Pressure Measuring Instrument.

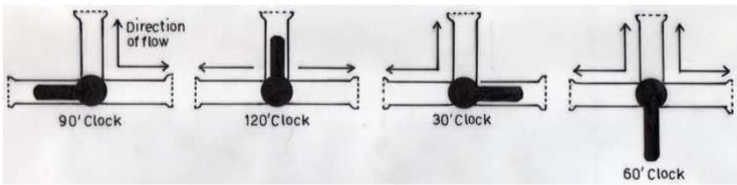

Figure 2: Different Positions of the Lever in a Stopcock

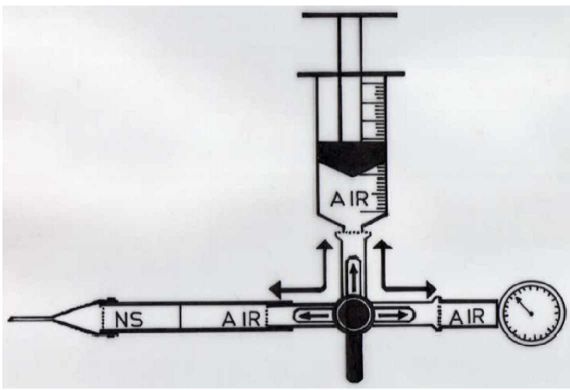

Figure 3: Set up of the Compartment Pressure Measuring Device

Figure 4: A Case of 12 Hour Old Electrical Burn Forearm and Hand with Compartment Syndrome, Fasciotomy was Done but the Patient Landed in Below Elbow Amputation

Figure 5: A 4 Day Old Case of # Both Bone Forearm (Inset Shows the x-ray) with Compartment Syndrome Along with Blisters on the Skin, Subcutaneous Fasciotomy was Done and the Patient Improved