Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/jcot

Original Article

Osteofascial compartment pressure measurement in closed limb injuries – Whitesides' technique revisited

Rajendra Kumar Beniwal MBBS, MS^{a,*}, Abhishek Bansal MS, DNB, MRCS^b

^a Senior Specialist and Asst. Professor, Central Institute of Orthopaedics, Safdarjang Hospital, New Delhi 110029, India

^b Senior Consultant, Max Hospital, Vaishali, Ghaziabad, UP, India

ARTICLE INFO

Article history:

Received 10 November 2015

Accepted 10 January 2016

Available online 10 February 2016

Keywords:

Compartment pressure

Compartment syndrome

Fasciotomy

Whitesides' technique

Closed fracture in limbs

ABSTRACT

Introduction: Regular monitoring of tissue compartmental pressures and hence a timely intervention in patients with impending compartment syndrome has been shown to prevent morbidity and permanent disability.

Material and methods: Intra-compartmental pressure in flexor compartment of forearm and various compartments of legs following recent trauma presenting within 6 h of injury was carried out in 30 subjects using Whitesides' technique and patients were classified into 3 categories for treatment purposes i.e., Category I: pressure <30 mmHg, Category II: pressure 30–40 mmHg and Category III: pressure >40 mmHg.

Results: Category I had 17 subjects, Category II had 6 subjects whereas 7 subjects fell into Category III. 6 patients out of the 30 studied needed fasciotomy, out of which 5 had fair or good result.

Conclusion: Whitesides' technique, though not much widely favoured, is a safe, inexpensive, easily assembled and reliable method for measurement of intra-compartmental pressure as a guide for decompression.

© 2016 Delhi Orthopedic Association. All rights reserved.

1. Introduction

Elevation of compartment pressure beyond a critical level can jeopardize perfusion of limbs leading to myonecrosis, rhabdomyolysis and myoglobinaemia, leading to organ damage and possible limb amputation. Early suspicion and timely fasciotomy should be performed to prevent such complications. Common causes of acute compartment syndrome are fractures, ischaemia-reperfusion injury, haemorrhage, intravenous/intra-arterial drug injection, prolonged limb

compression, crush injury, burns and septic conditions, such as meningococcal sepsis.

Measurement of compartment pressures in limb trauma has been recommended to be the basis of decision for fasciotomy in most studies.^{1,2} Fasciotomy should be performed when the difference between the diastolic blood pressure and compartment pressure (ΔP = differential pressure) is less than 30 mmHg (ΔP = diastolic blood pressure – compartment pressure) according to one study.³ Others prefer to use the mean arterial pressure (MAP) instead of the diastolic pressure to determine the ΔP .² These values of compartment pressure, and recommendations

* Corresponding author. Mobile: +91 9811013747; fax: +91 01126192467.

E-mail address: drkbeniwal@gmail.com (R.K. Beniwal).

<http://dx.doi.org/10.1016/j.jcot.2016.01.001>

0976-5662/© 2016 Delhi Orthopedic Association. All rights reserved.

for fasciotomy, are widely used for clinical decision-making in adult patients, as well as in adolescents and children.²

Compartment pressures can be measured by several techniques. Whitesides et al., in 1975, introduced needle manometry. Since then, various other methods have been developed, such as the Wick catheter, the slit catheter, the solid-state transducer intra-compartment catheter, the myo-press catheter, the Stryker device and the transducer-tipped fibre-optic catheter.⁴⁻⁹ However, simple needle manometry may be considered the best method. It is used most often because it is the easiest and cheapest way of measuring compartment pressure, and has proved to be at least as accurate as other methods.^{10,11}

The aim of the present prospective clinical study was to evaluate the rise of tissue pressure in the traumatized limb and its significance as a tool in determining the “critical compartmental pressure” as a guide to fasciotomy using needle manometry.

2. Materials and methods

A clinical study of intra-compartmental pressure in flexor compartment of forearm and various compartments of legs following recent trauma was carried out in 30 subjects at a tertiary care centre in India. Only those patients presenting within 6 h of injury were included in the study. Patients with compound fractures and who presented after 6 h of injury were excluded from the study. Informed consent was taken from each individual.

All the patients were evaluated for the presence of any associated life-threatening emergency and as such resuscitation was carried out for these patients. Each patient was examined in detail with regard to history of trauma and symptomatology. A detailed examination of the patient was then made and recorded (Fig. 1). X-ray of the injured extremity was taken in antero-posterior and lateral views (Fig. 2).

The tissue pressure of the compartment was measured using Whitesides' technique involving the following equipment (Fig. 3):

1. One plastic extension tubing (sterilized i.v. drip set).
2. Two standard 18-gauge needles.
3. One 20 cc syringe.
4. One 3-way stop cork.
5. One vac of sterilized normal saline.
6. One mercury manometer with an adapter in the tubing.

The area of the extremity under evaluation was cleaned and prepared. The syringe with the plunger at 15 cc mark, 3-way stop cork, i.v. drip set and an 18-gauge needle were connected and saline was aspirated from the vac with approximately 3/4th the length of the tubing. Then the 3-way cork was turned to close off this tube to prevent loss of saline during transfer of the needle. The 18-gauge needle was then inserted into the muscle of the compartment under study. The rubber tubing of mercury manometer with the adapter was then attached to the 3-way stopcock. The stopcock was then turned to such a position that the syringe was open to both the manometer and the compartment under study. The plunger of the syringe was very gradually depressed watching the column of saline. The

Fig. 1 – Clinical photograph of left leg with impending compartment syndrome.

Fig. 2 – X-ray picture of the same patient.

mercury manometer rose as the pressure within the system rose. When the pressure rose to just beyond the tissue pressure, the saline started to flow in the tubing and a small amount of saline was injected into the compartment. As soon as the saline column started to move, the pressure on the syringe plunger was stopped and the reading on the mercury manometer was recorded, which represented the tissue pressure (Fig. 4). A total of three readings were obtained each time.

The tissue pressure in the involved extremity was measured in all the compartments and the highest tissue pressure in any of the compartments was considered the actual pressure.

Fig. 3 – Equipment required for using Whitesides' technique for compartment pressure monitoring.

Patients were classified into 3 categories depending on the range of tissue pressure recordings. The treatment was based on the pressure category.

Category I: pressure <30 mmHg – treated conservatively by well-padded plaster slab and elevation.

Category II: pressure 30–40 mmHg – monitored 6 hourly (watch over phase) and treated conservatively by well-padded plaster slab and elevation.

Category III: pressure >40 mmHg – considered “Critical Pressure” for decompressive fasciotomy.

In majority of the cases needing fasciotomy, the four compartments para-fibular approach described by Matsen et al.¹⁵ was used. The fasciotomy wound was left open and patient

Fig. 4 – Clinical photograph of Whitesides' technique being used for compartment pressure monitoring.

condition was monitored after that. The wound was let to heal with secondary intention, and later, a skin grafting was done.

3. Results

66.67% ($n = 20$) patients were between the age group of 20–40 years with vehicular accidents being the most common mode of injury (50%) besides fall from height (16.66%), fall of heavy object on the limb (13.33%), blow from stick (13.33%) and tight plastering (6.67%) (Table 1). All the included patients had fracture of the bones in involved extremity with upper extremity involvement in 20% and leg involvement in 80% of the cases. 66.67% ($n = 20$) cases had fracture in the metaphyseal region of the bone.

The normal tissue pressure was measured simultaneously in the uninvolved extremity measure between 0 and 20 mmHg (average 13 mmHg). Based on the tissue pressure in the involved extremity, the cases were categorized (Table 2):

Category I: pressure <30 mmHg – 17 cases (56.67%). 5 (30%) cases were upper extremity trauma with 12 (70%) being leg injuries. Average tissue pressure was 24 mmHg.

Category II: pressure 30–40 mmHg – 6 cases (20%). 1 (16.66%) case was forearm involvement with 5 (83.66%) cases being leg involvement. Average tissue pressure was 34.66 mmHg.

Category III: pressure >40 mmHg – 7 cases (23.33%). All the cases (100%) were leg compartment involvement. Average tissue pressure was 45.14 mmHg.

Out of the 6 patients (20%) who underwent fasciotomy, 5 underwent the procedure within first 24 h of the injury and had uniformly good outcome. The one who underwent fasciotomy after 3 days due to late presentation had poor or no recovery with infection thereby highlighting the importance of time frame for such a procedure.

4. Discussion

Acute compartment syndrome is a surgical emergency. Early diagnosis and treatment are of utmost importance in order to

Table 1 – Causes of injury in the present study.

Cause of injury	% age occurrence
Vehicular accidents	50
Fall from height	16.66
Fall of heavy object on the limb	13.33
Blow from stick	13.33
Tight plastering	6.67

Table 2 – Categorization of cases based on measured compartmental pressure.

Category	Compartment pressure (mmHg)	No. of cases (% age)	Average tissue pressure (mmHg)
I	<30	17 (56.67)	24
II	30–40	6 (20)	34.66
III	>40	7 (23.33)	45.14

avoid long-term disability. The clinical features cannot always be relied upon for diagnosis. The diagnosis can be easily established in the conscious adult patient but could be missed in children and polytraumatized patients as physical examination has poor sensitivity and specificity.¹² Current concepts favour two methods for diagnosis of compartment syndrome. The first concept uses CP values higher than 30–40 mmHg and the second uses ΔP = differential pressure lower than 30 mmHg as an indication for fasciotomy.¹³ The second concept relies on Whitesides' theory, which states that blood pressure can decrease or increase the effect of CP on the tissue perfusion.^{12,14} Compartment pressure measurement is the most reliable and objective method for early diagnosis. A number of devices are available to measure intra-compartmental interstitial pressure like Wick catheter, simple needle manometry, slit catheter, side-porter needle and fibre-optic transducer. Most of these devices are either expensive or not easily available in developing countries. Wick catheter and slit catheter have the danger of being left behind in the compartment. Whitesides' apparatus is one of the devices used for measurement of tissue pressure. The apparatus is simple and effective and can be assembled with the materials easily available in any hospital ward or emergency room. Moreover, it is inexpensive, safe, reproducible and most importantly ideal for use in peripheral hospitals in a developing nation like ours.

It is evident from our study that young patients, especially men and those sustaining road traffic accidents, are at increased risk of developing compartment syndrome.

The critical level of absolute tissue pressure above which decompression should be performed has always been variably reported as 30 mmHg, 40 mmHg and 50 mmHg.

In our study, we used the critical pressure limit of >40 mmHg as the cut-off. In a study using this pressure measurement for surgical intervention, it was demonstrated that many unnecessary fasciotomies were avoided, while patients who had developed an increase in compartmental pressure sufficient to cause obvious tissue compromise as seen at the time of fasciotomy were identified correctly. Had we used the absolute pressure of more than 30 mmHg as the threshold for decompression, as recommended by many authors, then 10 out of 30 patients (33.33%) would have had an unnecessary fasciotomy. None of the patients in our series had any stigmata of compartment syndrome during a minimum follow-up of 6 months. This proves that not a single case of compartment syndrome remained undiagnosed on taking the pressure of more than 40 mmHg as the criterion for diagnosing acute compartment syndrome.

From our study, we conclude that intra-compartmental pressure monitoring is a reliable and objective method for early and accurate diagnosis of compartment syndrome. Early diagnosis can minimize the soft tissue damage and therefore improve the long-term results. We therefore believe that all patients with closed fractures of leg should have routine anterior compartmental monitoring. Whitesides' technique, though not much widely favoured, is a safe, inexpensive, easily assembled and reliable method for measurement of intra-compartmental pressure in a peripheral set-up in developing countries. Moreover, in unconscious and moribund

patients who may not show the obvious clinical signs of compartment syndrome, this simple yet very effective technique can prove to be of great value.

Conflicts of interest

The authors have none to declare.

REFERENCES

1. Willis RB, Rorabeck CH. Treatment of compartment syndrome in children. *Orthop Clin North Am.* 1990;21:401–412 [PubMed: 2183136].
2. Heckman MM, Whitesides TE, Grewe SR, Rooks MD. Compartment pressure in association with closed tibial fractures. The relationship between tissue pressure, compartment and the distance from the site of the fracture. *J Bone Joint Surg Am.* 1994;76:1285–1292 [PubMed: 8077257].
3. Blick SS, Brumback RJ, Poka A, Burgess AR, Ebraheim NA. Compartment syndrome in open tibial fractures. *J Bone Joint Surg Am.* 1986;68:1348–1353 [PubMed: 3782206].
4. Velmahos GC, Toutouzas KG. Vascular trauma and compartment syndromes. *Surg Clin North Am.* 2002;82:125–141 [PubMed: 11905942].
5. Oslen SA, Glasgow RR. Acute compartment syndrome in lower extremity trauma. *J Am Acad Orthop Surg.* 2005;13:436–444 [PubMed: 16272268].
6. Allen MJ, Stirling AJ, Crawshaw CV, Barnes MR. Intracompartmental pressure monitoring of leg injuries: an aid to management. *J Bone Joint Surg Br.* 1985;67:53–57 [PubMed: 3968144].
7. Rorabeck CH. The treatment of compartment syndromes of the leg. *J Bone Joint Surg Br.* 1984;66:93–97 [PubMed: 6693486].
8. Whitesides Jr TE, Haney TC, Morimoto K, Harada H. Tissue pressure measurements as a determinant for the need of fasciotomy. *Clin Orthop Relat Res.* 1975;113:43–51 [PubMed: 1192674].
9. Gelberman RH, Garfin SR, Hergenroeder PT, Mubarak SJ, Menon J. Compartment syndrome of the forearm: diagnosis and treatment. *Clin Orthop Relat Res.* 1981;161:252–261 [PubMed: 7307388].
10. Schwartz Jr JT, Brumback RJ, Lakatos R, Poka A, Bathon GH, Burgess AR. Acute compartment syndrome of the thigh: a spectrum of injury. *J Bone Joint Surg Am.* 1989;71:392–400 [PubMed: 2925712].
11. Brostrom LA, Stark A, Svartengren G. Acute compartment syndrome in forearm fractures. *Acta Orthop Scand.* 1990;61:50–53 [PubMed: 2336952].
12. McQueen MM, Christie J, Court-Brown CM. Acute compartment syndrome in tibial diaphyseal fractures. *J Bone Joint Surg Br.* 1996;78:95–98 [PubMed: 8898136].
13. Mubarak SJ, Owen CA, Hargens AR, Garetto LP, Akesson WH. Acute compartment syndromes: diagnosis and treatment with the aid of the Wick catheter. *J Bone Joint Surg Am.* 1978;60:1091–1095 [PubMed: 721856].
14. McQueen MM, Court-Brown CM. Compartment monitoring in tibial fractures: the pressure threshold for decompression. *J Bone Joint Surg Br.* 1996;78:99–104 [PubMed: 8898137].
15. Matsen III FA, Winquist RA, Krugmire Jr RB. Diagnosis and management of compartmental syndromes. *J Bone Joint Surg [Am].* 1980;62-A:286–291.