Acute compartment syndrome

WHO IS AT RISK?

M. M. McQueen, P. Gaston, C. M. Court-Brown

From the Royal Infirmary of Edinburgh, Scotland

We have analysed associated factors in 164 patients with acute compartment syndrome whom we treated over an eight-year period. In 69% there was an associated fracture, about half of which were of the tibial shaft. Most patients were men, usually under 35 years of age. Acute compartment syndrome of the forearm, with associated fracture of the distal end of the radius, was again seen most commonly in young men. Injury to soft tissues, without fracture, was the second most common cause of the syndrome and one-tenth of the patients had a bleeding disorder or were taking anticoagulant drugs. We found that young patients, especially men, were at risk of acute compartment syndrome after injury. When treating such injured patients, the diagnosis should be made early, utilising measurements of tissue pressure.

J Bone Joint Surg [Br] 2000;82-B:200-3.

Received 12 January 1999; Accepted after revision 15 June 1999

The most important determinant of a poor outcome from acute compartment syndrome after injury is delay in diagnosis.¹⁻⁵ The complications are usually disabling and include infection, contracture and amputation. One of the main causes of delay may be insufficient awareness of the condition. While it is acknowledged that children, because of difficulty in assessment, and hypotensive patients are at risk, most adults who develop acute compartment syndrome are not hypotensive. Awareness of the risk of the syndrome may reduce delay in diagnosis. Continuous monitoring of compartment pressure may allow the diagnosis to

be made earlier and complications to be minimised.^{5,6} Since the necessary resource may not be readily available we attempted to identify patients who were at risk and would benefit from monitoring of compartment pressure.

Patients and Methods

Data were collected from all adult patients with a recognised acute compartment syndrome who came to our Orthopaedic Trauma Unit between 1988 and 1995, inclusive. This is the only trauma unit serving a population of 650 000 and therefore has a high rate of capture. We excluded patients with postischæmic acute compartment syndrome, since they were treated in the vascular unit. Patients with crush syndrome were included.

Acute compartment syndrome was diagnosed either clinically or by monitoring of compartment pressure. We nominated a differential pressure of less than 30 mmHg between the tissue pressure and diastolic blood pressure as the threshold for fasciotomy.⁶ The diagnosis was confirmed by escape of muscle groups at fasciotomy.⁷ The classification systems of Tscherne⁷ and Gustilo^{8,9} were used for the tibial diaphyseal fractures. The chi-squared test with Yates' correction was used for comparison of age incidences.

Results

There were 164 patients with an acute compartment syndrome, 149 men and 15 women, with a mean age of 32 years (14 to 88). The mean age for men was 30 years and for women, 44 years. The average annual incidence was 7.3 per 100 000 for men and 0.7 per 100 000 for women (Fig. 1). The primary condition causing acute compartment syndrome was a fracture, which occurred in 113 patients (69%). The two most common were of the diaphysis of the tibia in 59 patients (36%) and of the distal radius in 16 (9.8%). Injury to the soft tissues without a fracture occurred in 38 patients (23.2%) (Table I).

Table II shows the causes of injury. Road-traffic accidents (RTA) were the most common, followed by sport. Almost 10% of patients had a tissue-crushing injury. Two patients in the spontaneous group were receiving anticoagulants; one had swelling after a deep-venous throm-

M. M. McQueen, MD, FRCS Ed(Orth), Consultant Orthopaedic Surgeon
P. Gaston, FRCS, Clinical Research Fellow
C. M. Court-Brown, MD, FRCS Ed(Orth), Consultant Orthopaedic Surgeon
Department of Orthopaedics, The Royal Infirmary of Edinburgh NHS Trust, Lauriston Place, Edinburgh, EH3 9YW, UK.

Correspondence should be sent to Miss M. M. McQueen.

©2000 British Editorial Society of Bone and Joint Surgery
0301-620X/00/29799 \$2.00

Fig. 1

The average annual age and gender specific incidence per 100 000 of the population for all cases of acute compartment syndrome between 1988 and 1995.

Table I. Conditions causing acute compartment syndrome in the 164 patients identified

Underlying condition	Number of patients	Percentage
Tibial diaphyseal fracture	59	36.0
Soft-tissue injury	38	23.2
Distal radial fracture	16	9.8
Crush syndrome	13	7.9
Diaphyseal fracture of the radius and/or ulna	13	7.9
Femoral fracture	5	3.0
Tibial plateau fracture	5	3.0
Hand fractures	4	2.5
Tibial pilon fractures	4	2.5
Foot fractures	3	1.8
Ankle fracture	1	0.6
Elbow fracture-dislocation	1	0.6
Pelvic fracture	1	0.6
Fracture of the humerus	1	0.6
Total	164	100.0

Table II. Modes of injury for all 164 acute compartment syndromes

Mode	Number	Percentage
Sport	33	20.1
RTA pedestrian	20	12.2
Crushing injury	16	9.8
RTA driver	15	9.2
Fall from standing height	14	9.2
Attempted suicide/ drug overdose	15	8.5
Direct blow	13	7.9
Fall from height	11	6.7
Penetrating injury	7	4.3
RTA motorbike	9	5.5
Spontaneous	5	3.0
RTA passenger	4	2.4
Assault	2	1.2

bosis and one had a severe infection around the elbow. No cause was detected in one patient. Four other patients had bleeding disorders, one with a tibial fracture, one with a fracture of the distal radius and two with soft-tissue injury.

Fractures of the tibial diaphysis. A total of 59 patients had acute compartment syndrome after fracture of the tibial diaphysis; 55 were men and four were women with a mean age of 30 years (14 to 86). The average annual incidence for men was 6.9 per 100 000 and for women 0.2 per 100 000. In the same period 1349 fractures of the shaft of the tibia were treated, giving an incidence of acute compartment syndrome of 4.3%. Of the 821 patients under 35 years of age, 5.9% had an acute compartment syndrome. The incidence was threefold less in those aged over 35 years ($p < 0.001$).

Among the 59 patients with a tibial fracture who had an acute compartment syndrome, a sports injury, mainly soccer, was the cause in 27, an RTA in 20, a fall in 11 and a direct blow in one. We considered that 59% of patients had a low-energy type of injury. Ten patients had open and 49 had closed fractures. The types of closed fracture were Tscherne type C1 (28 patients), C2 (16), C0 (3) and C3 (2). Five of the open fractures were Gustilo type 1, three were type 2, and two type 3 of which one was 3A and one 3B. During the same time period 306 open tibial fractures were treated, giving an incidence of 3.3% in these injuries. A total of 45 patients was treated by either reamed or unreamed intramedullary nailing and 14 by external fixation. The incidence of acute compartment syndrome was 5.5% of 810 tibial fractures treated by intramedullary nailing and 12.2% of 114 fixed externally.

All four compartments of the leg were involved in 18 patients at the time of surgical release. The anterior compartment was also affected in the other 41 patients; in 30 it was isolated, in six with accompanying involvement of the lateral compartment and in five of the deep posterior compartment.

Soft-tissue injury. There were 38 patients (23.2%) with a soft-tissue injury with no associated fracture, 32 men and six women. Their mean age was 38 years (15 to 88). Most had sustained a direct blow to the affected muscle compartment, or an injury with a major crushing component. There were a number of other less common modes of injury

Table III. Causes of soft-tissue injury in 39 patients

Cause	Number	Percentage
Direct blow	10	25.6
Crushing injury	8	20.5
Penetrating injury	5	12.8
Spontaneous	5	12.8
RTA pedestrian	4	10.3
Fall from standing height	3	7.7
Injection	2	5.1
RTA motorbike	1	2.6
Sport	1	2.6
Total	39	100.0

(Table III). Four (10.3%) of this group were either taking anticoagulants or had a bleeding disorder. Only four had other associated injuries. A large range of compartments was affected. In 21 patients the leg was involved, in four of whom all four compartments were concerned. In nine patients the forearm, in five the quadriceps compartment, in two the foot and in one the hand were affected.

Fractures of the distal radius. There were 16 patients (9.8%) with an acute compartment syndrome complicating fracture of the distal radius, 15 men, nearly all young, and one woman, with a mean age of 26 years (14 to 51). During the same period, 6395 fractures of the distal radius were treated giving an average incidence of 0.25%. Of the 1007 patients aged 35 years or under, 1.4% had acute compartment syndrome, while 0.04% of 5388 over 35 years were affected ($p < 0.001$). Nine of the 16 patients had high-energy transfer injuries, and three had multiple injuries.

Of the 15 patients who had involvement of the volar compartment of the forearm, one also had involvement of the interosseous compartments of the hand and in one patient only these areas of the hand were affected.

Diaphyseal fractures of the forearm. There were 13 patients (7.9%) with acute compartment syndrome after diaphyseal fractures of the radius and/or ulna. All were men with a mean age of 33 years (14 to 60). During this period 422 such fractures of the radius and ulna were treated, giving an incidence of 3.1%. The incidences for patients aged under and over 35 years were similar at 3.2% and 2.8%, respectively, but with a preponderance of young men. Most had high-energy exchange injuries as seven patients had either multisystem or multiple orthopaedic injuries.

Discussion

We have shown clearly that young people, especially men, have the highest incidence of acute compartment syndrome. This is particularly evident for fractures of the tibial diaphysis and of the distal radius which have threefold and 30-fold increases, respectively, for younger age groups. Why is this? It is possible that young men have relatively large muscle volumes, while the compartment size (an inelastic fascial envelope) does not change after growth is complete. Thus, young men may have less space for

swelling of the muscle after injury. Young men are also more likely to sustain high-energy exchange injuries, although the direct effect is not clear from our study because such injuries predominated in metaphyseal and diaphyseal fractures of the forearm, but not in diaphyseal fractures of the tibia.

What is it about older people that protects them from acute compartment syndrome?⁷ They may have smaller, hypotrophic muscles, and their relatively higher blood pressure may provide tolerance for higher tissue pressure. While there has been controversy in deciding what pressures constitute an acute compartment syndrome the importance of the difference between perfusion pressure and tissue pressure has been shown both experimentally and clinically.^{6,10,11} Hypertension was also noted to have a protective effect when the thresholds of tissue pressure for viability of the peripheral nerves were investigated.¹²

Early diagnosis and treatment are of the utmost importance in order to avoid long-term disability after acute compartment syndrome.^{1-3,5,13} We believe that awareness of the possibility of acute compartment syndrome among nursing and medical staff is the most important factor contributing to an early diagnosis. Knowing that specific groups of patients are at risk should heighten awareness of the condition. These are the patients to whom pressure-measuring devices should be applied promptly, with urgent fasciotomy should the measurements be abnormal.

In our study we have identified the broad spectrum of conditions which may be complicated by acute compartment syndrome. Neither children nor patients with post-ischaemic acute compartment syndromes were included and it must be stressed that these are also particular groups at risk as are hypotensive or unconscious patients.¹⁴⁻¹⁷ We do not often encounter patients with penetrating injuries and cannot comment about their vulnerability to the syndrome.

While fracture of the tibial diaphysis was the most common condition associated with acute compartment syndrome we were not able to explain why the ratio of high-energy to low-energy exchange injury was about equal.¹⁸ Analysis of our results⁸ suggested that lower-energy injury caused less disruption of the tissues and increased the risk of acute compartment syndrome. While it has often been suggested that there may be some protection afforded by 'autodecompression' of compartments the possibility of acute compartment syndrome in severe fractures should never be dismissed. The increased prevalence of acute compartment syndrome in externally fixed tibial fractures has not previously been noted. Intramedullary nailing of tibial fractures has been suggested as a possible, although not confirmed, cause of acute compartment syndrome.^{19,20} During the period of our study closed external fixation was usually carried out with the leg on a traction table and it is possible that the distraction of the fracture was a precipitating factor for an acute compartment syndrome. These figures should not be interpreted as showing that external

fixation has a higher risk for this complication since they were not derived from a randomised study.

Injury to soft tissues without fracture is a common cause of acute compartment syndrome, but is probably the condition for which there is least awareness of the risk. This is particularly so in young men, especially if they have a known bleeding disorder or are having anticoagulant treatment.

Fractures of the distal radius and diaphyseal fracture of the forearm were unlike tibial diaphyseal fractures in that acute compartment syndrome occurred most commonly after high-energy injury. Although this may be because forearm compartments are less well defined than those in the leg and therefore their disruption is less important, we believe that high-energy injury and young men are inextricably linked and the predominant risk factors remain gender and age.

As a result of our study we recommend that the following should have monitoring of the compartment pressure: (1) those with fractures of the tibial diaphysis, especially young men; (2) young patients with high-energy injury to the forearm diaphysis or distal radius; (3) patients with high-energy exchange fractures of the tibial metaphysis; and (4) young men with injury to the soft tissues or those with a bleeding diathesis.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References

1. McQuillan WM, Nolan B. Ischaemia complicating injury: a report of thirty-seven cases. *J Bone Joint Surg [Br]* 1968;50-B:482-92.
2. Matsen FA, Clawson DK. The deep posterior compartmental syndrome of the leg. *J Bone Joint Surg [Am]* 1975;57-A:34-9.
3. Rorabeck CH. The treatment of compartment syndromes of the leg. *J Bone Joint Surg [Br]* 1984;66-B:93-7.
4. DeLee JC, Stiehl JB. Open tibia fracture with compartment syndrome. *Clin Orthop* 1981;160:175-84.
5. McQueen MM, Christie J, Court-Brown CM. Acute compartment syndrome in tibial diaphyseal fractures. *J Bone Joint Surg [Br]* 1996;78-B:95-8.
6. McQueen MM, Court-Brown CM. Compartment monitoring in tibial fractures: the pressure threshold for decompression. *J Bone Joint Surg [Br]* 1996;78-B:99-104.
7. Oestern H-J, Tscherne H. Pathophysiology and classification of soft tissue injuries associated with fractures. In: Tscherne H, Gotzen L, eds. *Fractures with soft tissue injuries*. Berlin, etc: Springer Verlag, 1984:1-9.
8. Gustilo RB, Anderson JT. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analysis. *J Bone Joint Surg [Am]* 1976;58-A:453-8.
9. Gustilo RB, Mendoza RM, Williams DN. Problems in the management of type III (severe) open fractures: a new classification of type III open fractures. *J Trauma* 1984;24:742-6.
10. Whitesides TE Jr, Haney TC, Morimoto K, Harada H. Tissue pressure measurements as a determinant for the need of fasciotomy. *Clin Orthop* 1975;113:43-51.
11. Heppenstall RB, Sapega AA, Scott R, et al. The compartment syndrome: an experimental and clinical study of muscular energy metabolism using phosphorous nuclear magnetic resonance spectroscopy. *Clin Orthop* 1988;226:138-55.
12. Gelberman RH, Szabo RM, Williamson RV, et al. Tissue pressure threshold for peripheral nerve viability. *Clin Orthop* 1983;178:285-91.
13. Schwartz JT, Brumback RJ, Lakatos R, et al. Acute compartment syndrome of the thigh: a spectrum of injury. *J Bone Joint Surg [Am]* 1989;71-A:392-400.
14. Matsen FA III, Winquist RA, Krugmire RB Jr. Diagnosis and management of compartmental syndromes. *J Bone Joint Surg [Am]* 1980;62-A:286-91.
15. Hargens AR, Akeson WH, Mubarak SJ, et al. Tissue fluid pressures: from basic research tools to clinical applications. *J Orthop Res* 1989;7:902-9.
16. Willis RB, Rorabeck CH. Treatment of compartment syndrome in children. *Orthop Clin North Am* 1990;21:401-12.
17. Heppenstall RB, Sapega AA, Izant T, et al. Compartment syndrome: a quantitative study of high-energy phosphorus compounds using 31P-magnetic resonance spectroscopy. *J Trauma* 1989;29: 1113-9.
18. Court-Brown CM, McBurnie J. The epidemiology of tibial fractures. *J Bone Joint Surg [Br]* 1995;77-B:417-21.
19. McQueen MM, Christie J, Court-Brown CM. Compartment pressures after intramedullary nailing of the tibia. *J Bone Joint Surg [Br]* 1990;72-B:395-7.
20. Tornetta P III, French BG. Compartment pressures during non-reamed tibial nailing without traction. *J Orthop Trauma* 1997;11:24-7.