INTRACOMPARTMENTAL PRESSURE MONITORING OF LEG INJURIES

AN AID TO MANAGEMENT

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Acute compartment syndromes often develop insidiously and are often recognised too late to prevent permanent disability. Management is difficult as the compartment involved is seldom clinically apparent. By continuously monitoring the intracompartmental pressure these problems can be avoided: transient compartment syndromes can be differentiated from established ones and the correct compartment can be surgically decompressed.

Pressure monitoring techniques were used in 28 patients; three developed a compartment syndrome requiring surgical intervention, seven had a temporary increase of pressure and in 18 the pressure remained unaltered. Of the three with compartment syndromes, one was unusual in that it affected the thigh and another, unique in our experience, affected both the thigh and the calf.

Intracompartmental pressure monitoring significantly altered the management of two cases giving successful results with minimal intervention.

Severe soft-tissue trauma to any limb may give rise to an acute compartment syndrome, with subsequent disability if treatment is not rapidly instigated. Acute compartment syndromes of the lower leg are well-documented (Willhoite and Moll 1970; Matsen and Clawson 1975; Mubarak and Owen 1975; Mubarak et al. 1978) whereas those affecting the thigh are extremely rare (Mubarak and Owen 1975; Sheridan and Matsen 1976). Diagnosis by intracompartmental pressure monitoring using the slit-catheter technique has been reported (Rorabeck et al. 1980), but the value of continuous monitoring in the overall management of lower-limb trauma has not been fully appreciated.

Twenty-eight cases are reviewed where a compartment syndrome was considered possible and the role of continuous intracompartmental pressure monitoring in their management is discussed.

MATERIAL AND METHODS

Twenty-eight patients (27 men, average age 27 years, and 1 woman aged 26 years) with marked soft-tissue trauma to the lower limb were studied over a period of nine months. Twenty-three had sustained a fracture of the affected limb. In all patients the pressure in the anterior and deep posterior compartments of the affected lower leg was continuously monitored. Thigh pressure also was monitored in two patients and the superficial posterior compartment in a third.

The technique used (Barnes et al. 1984) is a modified version of Rorabeck's slit-catheter method used in conjunction with the continuous infusion technique described by Matsen (Matsen, Winquist and Krugmire 1980; Rorabeck et al. 1980). Each compartment is entered using a 16-gauge Medicut. The introducer is removed, leaving the cannula through which the slit catheter is inserted. The cannula is then removed leaving the slit catheter in situ. The catheter is filled with heparinised saline and connected by means of a three-way tap to a transducer which is connected to a pressure amplifier and a chart recorder. The pressure system is linked to an infusion pump which delivers 2 ml of heparinised saline per day to prevent clotting within the system. Recordings can then be made of the pressure within each compartment.

In those patients with tibial fractures the catheters were inserted under general anaesthesia (before the fracture was manipulated) at a site distant from the fracture in order to avoid converting a closed injury into a potentially open one. In the remainder, insertion of the catheter was aided by infiltrating the skin with local anaesthetic, care being taken not to inject into the actual compartment and so produce an artefactual rise in pressure. In all cases continuous monitoring was performed for at least 36 hours.

Regular clinical assessment was made of each limb
with particular reference to symptoms and signs suggestive of a compartment syndrome (Matsen 1980). In those patients in plaster and in those who needed considerable analgesia this proved extremely difficult; whereas intracompartmental pressure monitoring was used with equal facility both in these patients and in those on traction.

RESULTS

The results of the 28 patients in this series are summarised in Table I. Eighteen patients were normal, with regard to both clinical assessment and intracompartmental pressure recording. Seven patients were found by

Table I. Results of clinical assessment and intracompartmental pressure monitoring in 28 patients

<table>
<thead>
<tr>
<th>Patients</th>
<th>Fracture</th>
<th>Soft-tissue trauma only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td>Transient compartment syndrome</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Established compartment syndrome</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>28</td>
<td>23</td>
</tr>
</tbody>
</table>

pressure measurement to have a transient compartment syndrome but in only three were supportive clinical features present. The remaining three patients developed a full-blown compartment syndrome, both clinically and on pressure recording. Table II summarises the recorded details of those patients with transient compartment syndromes; the three patients with supportive clinical features all had temporary weakness of extensor hallucis longus and pain whose severity was disproportionate to the injury. As the pressure fell the clinical signs in these three patients regressed. The remaining three patients in whom a complete compartment syndrome developed are described below.

Case 8. A footballer sustained a direct blow to the anterior aspect of his left thigh. On presentation 18 hours later gross swelling was present with an anterior thigh compartment pressure of 70 mmHg. Fasciotomy relieved his symptoms; secondary closure was performed 10 days later. A fall in haemoglobin of 5 g/dl indicated the severity of his injury.

Case 9. A 22-year-old miner sustained a crush injury to his right calf. Medical advice was not sought initially, but when he attempted to return to work three days later the leg became swollen and tender. He came to the accident and emergency department, where thrombosis of the anterior tibial and peroneal veins was diagnosed and confirmed venographically. Four days after starting heparin anticoagulation the leg became swollen and exquisitely tender. The knee was held in some 70° of flexion with the foot in marked equinus. Any attempt to extend the knee, dorsiflex the foot or invert the ankle caused great distress. Pulses, capillary circulation and sensation were all normal. The partial thromboplastin time was within therapeutic limits. Anticoagulation was discontinued. Measurement of the pressure in all four calf compartments was normal with the exception of the superficial posterior compartment where a pressure of 78 mmHg was recorded. On aspiration of 50 ml of blood from this compartment the pressure dropped to 34 mmHg (Fig. 1). A further aspiration of 15 ml of blood reduced the pressure to 22 mmHg. The ankle could then be dorsiflexed to a neutral position, but 20° flexion deformity remained at the knee. He was allowed home two days later and returned to work within two weeks, with no residual stigmata of a compartment syndrome.

Table II. Intracompartmental pressures and clinical assessment in patients with a transient compartment syndrome.

<table>
<thead>
<tr>
<th>Case</th>
<th>Affected compartment</th>
<th>Time from accident to first reading (hours)</th>
<th>Initial pressure (mmHg)</th>
<th>Maximum pressure (mmHg)</th>
<th>Final pressure (mmHg)</th>
<th>Duration of pressure &gt; 40 mmHg (hours)</th>
<th>Clinical evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anterior calf</td>
<td>8</td>
<td>40</td>
<td>40</td>
<td>0</td>
<td>1</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>Anterior calf</td>
<td>2</td>
<td>70</td>
<td>75</td>
<td>20</td>
<td>2</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Anterior calf</td>
<td>2</td>
<td>26</td>
<td>42</td>
<td>25</td>
<td>5</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>Anterior calf</td>
<td>6</td>
<td>38</td>
<td>42</td>
<td>5</td>
<td>1</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>Anterior calf</td>
<td>6</td>
<td>59</td>
<td>62</td>
<td>1</td>
<td>1</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>Deep posterior calf</td>
<td>2</td>
<td>12</td>
<td>46</td>
<td>20</td>
<td>1</td>
<td>No</td>
</tr>
<tr>
<td>7</td>
<td>Deep posterior calf</td>
<td>6</td>
<td>53</td>
<td>60</td>
<td>25</td>
<td>1</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Case 10. A 17-year-old motorcyclist was admitted with a closed fracture of the lower third of the femur and an abdominal injury. Although he was suffering from shock, all peripheral pulses were present and there was no clinical evidence to suggest an acute compartment syndrome of the leg. Three-and-a-half hours later (after splenectomy) the thigh and the calf of the injured limb.
had become grossly swollen and the peripheral pulses could no longer be felt. Because he had been given opiates for pain, it was impossible to elicit any clinical signs of an acute compartment syndrome. However, the injured foot appeared engorged by comparison with the other foot which was pale. An arteriogram demonstrated an intact vascular supply to the limb. Pressure monitoring of the thigh and calf compartments indicated the extremely rare condition of an acute compartment syndrome affecting both the thigh and the calf; immediate and extensive fasciotomy was required. It was of interest that on applying skeletal traction on a Thomas' splint, an increase in pressure of 5 mmHg occurred in all compartments but this dropped again when traction was removed (Fig. 2).

Fasciotomy of the medial thigh compartment was performed initially while pressure monitoring was continued in each of the calf compartments; the changes in pressure in the calf compartments during the various stages of the surgical procedure are shown in Figure 3. After the thigh fasciotomy the pressure in the calf compartments fell to subcritical level thereby averting the need for a four-compartment fasciotomy of the calf. Pressure monitoring of the calf and thigh compartments was continued overnight and showed a gradual fall from subcritical to normal levels (Table III). The fasciotomy wound was closed after 10 days and the patient made a full and uneventful recovery.

**Fig. 1**

Case 9. Tracing showing the effect on intracompartmental pressure of aspiration of 50 ml blood from the superficial posterior compartment.

**Fig. 2**

Case 10. Tracings taken before operation showing the effects of skeletal traction (6.4 kg) on intracompartmental pressure. 
**DISCUSSION**

Continuous intracompartmental pressure monitoring has a number of advantages. It has been stressed how difficult it is clinically to elicit the signs and symptoms of an early compartment syndrome as these are often masked by analgesia or by the presence of plaster. Initially, medical staff are often inappropriately optimistic and once the diagnosis has been made it is often too late to avert irreparable damage to nerves and muscles. An objective method which provides continuous pressure assessment should allow earlier diagnosis: intracompartmental pressure monitoring is just such a technique and its influence on management can be profound.

The method also indicates with accuracy the compartment in which the pressure changes are occurring and allows the pressure to be monitored before, during and after operation. In Case 9 it was only monitoring the changing pressure resulting from aspiration of blood from the compartment that made it apparent that a compartment syndrome had been averted. In Case 10, if the calf compartments had not been monitored whilst the thigh fasciotomy was taking place, a further four-compartment fasciotomy of the leg would have been needlessly performed.

Cases of transient compartment syndrome can be safely diagnosed and the patient carefully watched without having to depend upon variable clinical signs. Transient rises in pressure can be safely monitored and as long as they do not remain above a pressure of 40 mmHg for more than six hours no permanent damage should result. If the pressure is above 50 mmHg, or is higher than 40 mmHg for more than six hours, we believe that fasciotomy should be performed.

Our three cases show that intracompartamental pressure monitoring is not only useful in diagnosing compartment syndromes but is also useful in their management. It is suggested that if a compartment syndrome is considered possible (for example with a fracture of a long bone associated with vascular damage) then monitoring should be started immediately. A pressure of 40 mmHg is regarded as highly suggestive of an early compartment syndrome. All compartments exhibiting a pressure greater than 40 mmHg for more than six hours or those showing a trend towards higher
pressures (even for a shorter time) should undergo a full compartment fasciotomy using the technique recommended by Mubarak and Owen (1972). The skin wound should be left open for 10 days, after which it should be closed either by applying Steristrips daily to bring the skin edges together, or by secondary suture. As compartment syndromes can develop at any time up to 64 hours after an episode of trauma it is recommended that the monitoring should be continued for at least this period of time.

The authors wish to thank Mr G. Bodiwala and the orthopaedic consultants of the Leicester Royal Infirmary for their permission to report their cases, Miss J. Wapples and Mrs L. Faulkner for their photographic assistance and Mrs C. A. Lindsey for her secretarial help.

REFERENCES


