Intramuscular pressures during exercise
Comparison of measurements with and without infusion

Jorma R. Styf1,2, Albert Crenshaw2 and Alan R. Hargens2

Our objective was to compare two techniques for measuring intramuscular pressures during dynamic exercise. In 20 volunteers muscle contraction and relaxation pressures were recorded with a noninfusion method (slit catheter) and with a microcapillary infusion method (Myopress catheter). Relaxation pressures measured by noninfusion were higher than those measured by infusion. The dynamic properties of the infusion method were higher as compared with the noninfusion method. The dynamic properties of the noninfusion method increased when microcapillary infusion was connected. This resulted in a lower recording of the muscle-relaxation pressure than without infusion. We concluded that the microcapillary infusion technique and the design of the tip of the Myopress catheter are better suited for pressure recordings during exercise.

History and clinical signs alone are in many cases not sufficient to establish the diagnosis of chronic compartment syndrome of the lower leg (Styf and Körner 1987). Therefore, intramuscular pressure recordings during exercise and at rest after exercise are helpful in diagnosing the causes of exercise-induced pain in the lower legs. Pressure recordings during exercise are also useful in the study of ergonomics and in mechanical studies of muscle tissue (Baumann et al. 1979, Mubarak 1981, McDermott et al. 1982, Körner et al. 1984, Sejerstedt et al. 1984).

We have studied catheter measurements, with and without infusion, for recording intramuscular pressures during exercise and at rest after exercise.

Subjects and methods

Pressure in the anterior tibial muscle was recorded unilaterally in asymptomatic legs of 6 women and 14 men with a mean age of 29 (17–56) years. Eleven subjects were healthy volunteers, and 9 had periostitis over the anterior margin of the tibia on the contralateral leg. Following a diagnostic pressure recording on the symptomatic leg, the subjects volunteered to participate in the present study. The study was approved by the ethics committees of the Universities of Gothenburg and California.

Pressure recordings. A dual-pressure recording system was employed for all the comparisons (Figure 1). The subjects were investigated at rest, during exercise, and at rest after exercise. All the subjects lay supine with the feet attached to an ergometer. The experimental setup, introduction of catheters, and the exercise test were described by Styf and Körner (1986). Subjects were allowed to exercise at a constant contraction frequency of 0.5–1.0 Hz until they experienced muscle fatigue. The minimum exercise time was 10 min in all but 1 subject, who developed muscle fatigue after 7 min.

The two catheters were introduced parallel to each other and 10–15 mm apart at the same depth into the anterior tibial muscle. The distance from the skin to the tip of the catheter was 45 mm. The first catheter was introduced 2 cm lateral to the tibial tuberosity, in a distal direction and parallel to the muscle fibers. The second catheter was introduced 10–15 mm lateral to the first catheter. The slit catheter was introduced via a 2.0-mm-diameter sheathed Venflon needle (Viggo, Helsingborg, Sweden). The Myopress catheter was introduced via a 1.7-mm-diameter sheathed Venflon needle. Both catheters were taped to the skin and via a transducer line connected to an electromagnetic transducer (Siemens-Elema 746 or Hewlett-Packard 1280) with low volume displacement and a multichannel ink recorder (Siemens-Elema, Mingograph 82).

Pressures were taken at rest without infusion and without injection of the catheters. Before the start of
exercise, the microcapillary infusion (1.5 mL/h) was turned on to the Myopress catheter, and resting pressures were taken again. The slit catheter was flushed once with 0.1 mL of sterile physiologic saline at the start of exercise. The function of the catheters was checked by response to external compression and to active muscle contraction.

Muscle-contraction pressure and muscle-relaxation pressure were recorded during exercise. Mean muscle pressure was calculated by adding the relaxation pressure to half the pressure amplitude. Dynamic properties of the pressure recording system were evaluated by rise time, which was defined as the time period required for the pressure to pass through the range of 10 to 90 percent of the final pressure value recorded at external compression.

In the first 14 subjects, recordings with the slit catheter noninfusion technique (Rorabeck et al. 1981) were compared with those of the Myopress catheter microcapillary infusion technique (Styf and Komer 1986). Microcapillary infusion at 1.5 mL/h was turned on to five of the slit catheters that showed decreased dynamic properties at the end of the exercise test.

In the second part of the study, the influence of infu-
Table 2. Results of simultaneous intramuscular pressure recordings with one infused and one noninfused Myopress catheter in 6 healthy subjects. Values are in mmHg. Mean ± SD.

<table>
<thead>
<tr>
<th></th>
<th>Infusion</th>
<th>Noninfusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intramuscular pressure at rest</td>
<td>8.7 ± 1.7</td>
<td>8.3 ± 1.9</td>
</tr>
<tr>
<td>Muscle contraction pressure</td>
<td>105 ± 26</td>
<td>88 ± 24</td>
</tr>
<tr>
<td>Muscle relaxation pressure at the end of exercise</td>
<td>14.3 ± 3.2</td>
<td>12.3 ± 2.9</td>
</tr>
<tr>
<td>Mean muscle pressure at the end</td>
<td>60 ± 4</td>
<td>50 ± 4</td>
</tr>
<tr>
<td>Intramuscular pressure at rest after exercise</td>
<td>14.4 ± 3.9</td>
<td>12.7 ± 2.7</td>
</tr>
</tbody>
</table>

The initial rise time was 60 ms for the microcapillary infusion system, and did not change during the test. The initial rise time for the noninfusion system was 110 ms, and rose in all but three catheters to values up to 2 seconds.

In the second part of the study, the need of pressure recordings during exercise was studied (Table 2). Five of the six noninfused Myopress catheters needed flushing with 0.1 mL of saline before pressures could be read during exercise. None of the catheters occluded during 30 min of exercise. All the noninfused catheters had blood clots at their distal tips following withdrawal of the catheters. The pressure recordings were not different. The results indicated that infusion is not necessary during short-term pressure recordings if catheters are flushed initially.

Discussion

Four possible explanations for recording increased muscle-relaxation pressure during exercise are 1) increased muscle-relaxation pressure that is related to a swelling (i.e., volume load) of the muscle tissue, as seen in patients with chronic compartment syndrome, 2) low dynamic properties of the pressure recording system, 3) remaining active muscle tension, and 4) volume loading by infusion.

Muscle-relaxation pressures in the anterior tibial muscle during exercise increase to 15–25 mmHg (2–3.3 kPa) in normal legs (Styf and Körner 1987) and to 34–55 mmHg in patients with chronic anterior compartment syndrome (Styf et al. 1987). The abnormal increase in muscle-relaxation pressure decreases blood flow and elicits the symptoms. Therefore, this parameter is diagnostically valuable. Pressure measurements during exercise may be erroneous if they are recorded with a method that lacks adequate dynamic response. This may result in an artificially high recording of muscle-relaxation pressure. Also, a catheter that has a clot at its tip or is occluded for some other reason records a falsely high pressure at rest after exercise.

Different values between muscle-relaxation pres-
sure and intramuscular pressure at rest after exercise recorded with the slit catheter are a consequence of its low dynamic properties. An analogous explanation is true for recordings of muscle-contraction pressure. When the dynamic properties of the recording system start to decrease during exercise, the relative duration of the contraction and relaxation times of the total cycle determines which of the pressure parameters (contraction or relaxation pressures) are less accurate. The pressure parameter with the shortest duration will be the first not to reach equilibrium. Similar results of decreased pressure amplitude with time using the slit catheter have been reported by Logan et al. (1983). Our results explain why pressure recordings during exercise with the slit catheter in other studies (Rorabeck et al. 1988), and also generally with catheter systems with low dynamic properties, are not useful in diagnosing the chronic compartment syndrome.

If the muscle is not fully relaxed between contractions, too high muscle-relaxation pressures will be recorded. This is also true for pressure recordings at rest after exercise. Simultaneous EMG recordings are helpful in excluding this possibility (Styf 1986, Järnhom et al. 1988).

The risk of volume load with a microcapsular infusion system is minimal because the compliance of muscle tissue at rest is high (Eliasen et al. 1974, Sejersted et al. 1984, Styf and Körner 1986). However, muscle compliance is lower during contraction. The risk of recording erroneously high muscle-contraction pressures is increased with a constant pump infusion technique. With the microcapsular nonconstant infusion technique, this risk is minimized (Styf and Körner 1986). In our study the infusion rate was zero when muscle contraction was 150 mmHg. For these reasons, this method is more suitable for recording muscle-contraction pressure during ergonomic studies.

The design of the tip of the catheter may be important when pressures are recorded during concentric and eccentric exercise. Several of our slit catheters were deformed. This may indicate that the petals were hooked up by the muscle tissue, causing trauma to the tissue. Therefore, the design of the tip of the slit catheter might be less suitable for recording intramuscular pressures during exercise.

We conclude that the microcapsular infusion technique and the design of the Myopress catheter are better suited for pressure recordings during exercise as compared with the slit catheter and the noninfusion technique.

References


Acknowledgements

This study has been supported by grants from the Gothenburg Medical Society, Fogarty International, NIH, and NASA.