The Amplitude of Pulse-Synchronous Intramuscular Pressure Oscillations ascertains the Diagnosis of Chronic Compartment Syndrome of the Leg

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Introduction: Measurement of intramuscular pressure (IMP) is commonly regarded as the gold standard to diagnose chronic anterior compartment syndrome (CACS) among patients with exercise-induced leg pain. Recent review studies have shown that the evidence for commonly used IMP criteria in diagnosing compartment syndromes are weak and the validity is questioned (1, 2). However, an objective diagnostic parameter is still needed. Several non-invasive techniques have been evaluated as an option for IMP including ultrasound, near infrared spectroscopy and MRI, but none of the techniques have gained widespread clinical acceptance. Therefore, improvement of IMP as a diagnostic parameter is essential. So far, no study has identified the clinical value of the amplitude of pulse-synchronous oscillations of the IMP at rest after exercise in diagnosing CACS among patients with exercise-induced leg pain.

The objective of the study was to evaluate if the amplitude of pulse-synchronous IMP oscillations at rest after an exercise test is a valid parameter that may aid in diagnosing CACS.

Methods: The study included 89 consecutive patients with a mean age of 31 years (49 women and 40 men) with suspected CACS, and 19 healthy subjects (10 women and 9 men), with a mean age of 28 years. The study was approved by the Regional Research Ethics Committee. All subjects gave their informed consent prior to participation in the study.

All the participants (patients and control subjects) performed an exercise test including maximum concentric dorsiflexion of the ankle joints in standing position. The test was designed to elicit the patients’ typical symptoms. The exercise continued until the participant was unable to continue due to pain and/or leg muscle fatigue. After the exercise test, IMP in the anterior compartment of the leg was recorded immediately (within 15-30 seconds) with a non-infusion pressure recording system. An 18 G (1.20x50 mm) needle with four side holes at the tip was introduced 45 mm parallel to the anterior tibialis muscle fibers and connected to the pressure recording system. The IMP was measured at rest with the participant in a supine position with the heel placed on a support to prevent external compression of the calf. The foot was kept in a relaxed neutral position to avoid undesired effects on the IMP. The IMP and the pulse-synchronous oscillations of the IMP were recorded continuously and displayed in real time on a monitor. Each patient underwent a clinical investigation by an orthopaedic surgeon before and after the exercise test. The diagnostic criteria for CACS were history of exercise-induced leg pain, pain over the anterior compartment of the leg induced by the exercise test, IMP at rest exceeding 30 mmHg one minute after exercise and exceeding 20 mmHg five minutes after exercise. All four criteria were required for the diagnosis of CACS. Electromyographic activity (EMG) recordings from the anterior tibialis muscle were used to ensure muscle relaxation (no muscle activity) at rest after exercise, thereby preventing a biased IMP. To calculate the sensitivity, specificity, positive predictive
value and negative predictive value of the amplitude of pulse-synchronous IMP oscillations as an indicator of CACS, a peak-to-peak amplitude larger than 2 mmHg one minute after exercise was chosen as the cut-off limit. Diagnosis of CACS was regarded as a reference. Local perfusion pressure was calculated as the difference between the mean arterial blood pressure and IMP. Pressure values are presented as mean and one standard deviation (SD). Differences between groups were determined with Mann-Whitney (U) test. Significance was set at p < 0.05. Correlations are given with Pearson’s r.

**Results:** The mean IMP at rest one minute after exercise was 54 (SD = 16) mmHg in 53 patients with CACS, 17 (SD = 6.0) mmHg in 36 non-CACS (other causes of leg pain) patients and 18 (SD = 5.2) mmHg in control subjects. The mean amplitude of the IMP oscillations was 7.1 (SD = 3) mmHg in patients with CACS, 1.3 (SD = 0.9) mmHg in non-CACS and 1.5 (SD = 0.6) mmHg in control subjects one minute after exercise. The amplitude of the IMP oscillations was significantly higher in CACS patients than in the control subjects (p < 0.0001), but no difference was found between non-CACS patients and control subjects (p = 0.61). The local perfusion pressure was 34 mmHg at one minute after exercise for the CACS patients compared with 71 mmHg for the non-CACS patients and 68 mmHg for the control group. Low local perfusion pressure correlated (r = 0.66) to high amplitudes of the IMP oscillations. The sensitivity of the amplitude to identify CACS patients was 96% while the specificity was 94%. The positive predicted value was 96% and the negative predicted value was 94%. The EMG signal at rest after exercise was silent in all participants.

**Discussion:** This study shows that the amplitude of the pulse-synchronous IMP oscillations at rest after an exercise test that elicits the patients’ leg pain are correlated with the increased IMP in patients with CACS. Oscillations with an amplitude of > 2 mmHg one minute after exercise have high sensitivity (96%) and specificity (94%) to identify CACS. The increased amplitude of IMP oscillations indicates the decreased compliance of the anterior compartment due to volume load and it is associated with the pathophysiological mechanisms of CACS. Amplitudes of 5.8 (SD = 2.7) mmHg in 36 CACS legs and less than 1 mmHg or not detectable in 85 non-CACS legs at rest after exercise have been reported(3). Therefore, 2 mmHg was selected as a cut-off value in the present study. This cut-off value resulted in both high sensitivity and high specificity in identifying patients with CACS. Experimental evidence from animal and human studies indicates that an elevated IMP may impede muscle capillary flood flow and that a local perfusion pressure below 30 mmHg in muscle may compromise tissue metabolism. Our result demonstrate that the amplitude of IMP oscillations were significantly higher in patients with local perfusion pressure less than 30 mmHg compared to patients with more than 30 mmHg. The 37 mmHg lower local perfusion pressure among the CACS patients compared to the non-CACS patients indicate that the local perfusion pressure during the exercise test decreased to approximately 50% in patients with CACS. Low local perfusion pressure was correlated with high amplitudes of the IMP oscillations, because the level of the local perfusion pressure is mediated by the IMP level.

The IMP may be elevated initially at rest after exercise due to the participant’s inability to completely relax the leg muscles due to leg pain (4). This was ruled out in the present study since all participants had a silent EMG-signal. Measurement of the amplitude does not impose any additional costs since the oscillations are easily obtained during clinical routine IMP measurements.
In conclusion, the amplitude of pulse-synchronous IMP oscillations is a valid parameter with high sensitivity and specificity to identify CACS patients among a large cohort of patients with exercise-induced leg pain. It may therefore improve the diagnostic accuracy.

**Significance:** Recent reviews report conflicting evidence regarding the validity of the IMP in diagnosing CACS and an overlap of commonly used IMP criteria. Recordings of IMP oscillations corroborate the IMP criteria and continuously assure catheter patency and may therefore improve the diagnosis of CACS.

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