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Measurement of tissue pressure with symptoms of compartment syndrome

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The increase in the tissue pressure (TP) in the compartment can be due to the internal pressure (contusion, swelling, inflammation), or due to the external pressure (tight bandage, pneumatic splint).

Injury and a deep thrombosis of a blood vessel lead to the stasis and subsequently to the lowering of arterial-venous gradient just the same as this associated with lowering of arterial medium pressure due to the shock with the excessive positioning of the extremity.

Our aim was to establish the value of TP and thus to prevent the symptoms of the compartment syndrome. The above-mentioned problem can be solved by measuring the tissue pressure in a real time, where the approximation of an invasive and a non-invasive pressure is proved by a comparative measurement.

Key words: tissue pressure, compartment syndrome, comparative measurement

1. Introduction

The paper deals with the methods of the measurement of the compartment syndrome symptoms. Compartment syndrome is defined as the state, which due to the increased TP in a closed space causes disorder of a blood circulation and thus changes the functions of the compartment tissues. The objective was to develop a non-invasive method of measurement of the compartment syndrome symptoms.

The major advantage is a painless performance of the measurement, which has less traumatic effect on a patient compared with an invasive measurement. From the doctor's viewpoint, the advantage lies in the readiness and the simplicity of the measurement.

The researchers in the world have been studied the problems of the comparative measurement for a long time. On the basis of the experimental measurements done we prove that there is a proportional functional dependence of the pressure in the compartment on the surface hardness. This dependence was described by a very close mathematical function with the correlation coefficient of 0.95. This can be proved by the so-called comparative measurement whereby it is necessary to find the way of the

application of sensors in the related locality. The application of sensors depends on the way of the therapy, but especially on the kind of the injury of the extremity.

2. Comparative measurement

This especially concerns the measurement carried out in order to compare an invasive and a non-invasive tissue pressures. Figure 1 shows the block scheme of the above-mentioned measurement. In such a measurement, two sensors are used, i.e. the invasive sensor, which is applied to the tissue, and the non-invasive sensor, which is applied between a muscular substance and, for example, a plaster of Paris, or bandage. The increase in a tissue pressure, being the result of the reasons mentioned, is recorded by the sensors, and the values measured are approximate. From the above it follows that in the future an urgent surgical intervention in the tissue will not be inevitable because a timely monitoring of the pressure changes, which should not go beyond the value of 40 torrs, will be sufficient. It is, however, necessary to mention that an important role is played by the disposition of the tissue and the present elements that are different, depending on individual patients and individual localities.

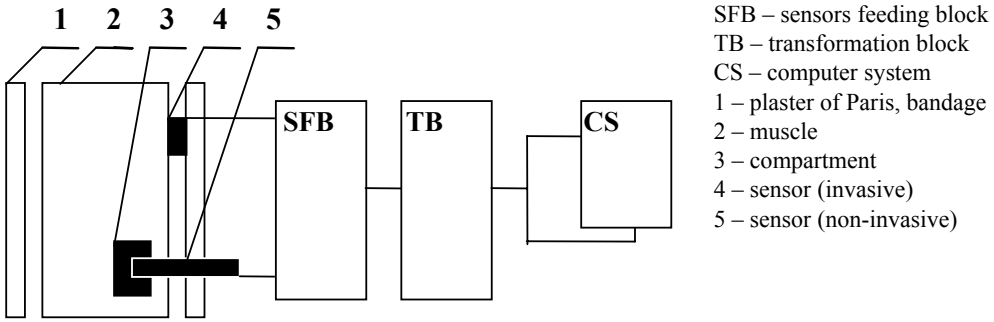


Fig. 1. The block scheme of the comparative measurement

The following part of the paper presents the applications of sensors in the comparative measurement and monitoring of a patient in terms of therapeutic methods. The applications are modelled in the locality of a thigh, i.e. the fracture of a femur.

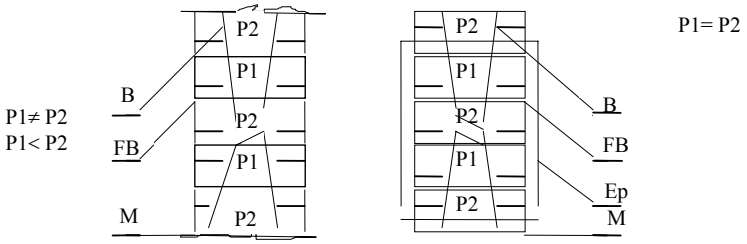
3. Application of sensors in comparative measurement of the compartment syndrome symptoms

During comparative measurement of the compartment syndrome symptoms the so-called muscle effect can appear. The muscle effect is a phenomenon characterized by the escape of the pressure, i.e. unproportional spread. This may appear when the

extremity is tightened in two distant places. Such a dispersion of the pressure can be seen in figure 2a. Carrying out the comparative measurement it is necessary to create such conditions that allow the pressure in the locality being considered to spread continually and proportionally.

As with the conservative treatment of the fractures a plaster of Paris is used, which is sufficiently strong, the condition is fulfilled. In the operation therapy with an external fixation, the injured extremity is free and the external fixer fixes it. In this case, a muscle effect appears. In order to avoid this and also to increase the accuracy of the measurement, it is necessary to use the equivalent to a plaster of Paris as it is illustrated in figure 2b.

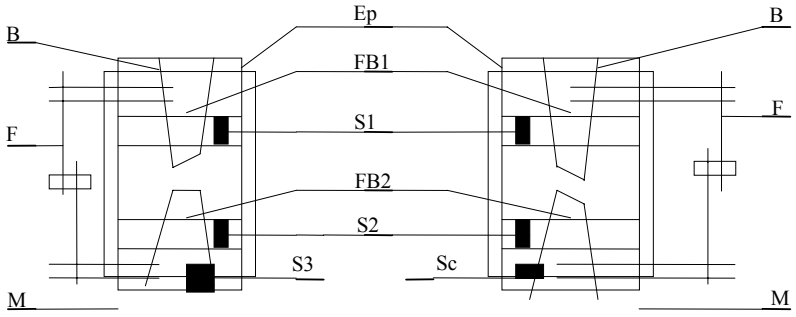
Ep – equivalent
of a plaster of Paris
FB – fixation belts
P1, P2 – pressure values
M – muscle
B – bone



a) b)

Fig. 2. Muscle effect

Sc – control sensor



a) b)

Fig. 3. The application of sensors

The application of sensors in measurements when the fragments of a broken bone are fixed by the external fixer is shown in figure 3a. Non-invasive sensors S1 and S2 are applied below and above the fracture and they are fixed by the fixing belts FB1, FB2. Sensor S3 is invasively applied out of the place of the fracture so that the pressure can be compared. The fixation belts secure the positions of sensors S1 and S2. As the equivalent to a plaster of Paris an elastic module EM is used to provide the required accuracy of the measurement. That is why a muscle effect does not occur in this case. With the monitoring, we do not apply invasively a sensor in the system;

instead of this a control sensor is applied non-invasively as far as possible from the place of the fracture. The method described is presented in figure 3b. The control sensor serves as an orientation parameter to compare the pressures from the sensors S1 and S2.

The sensors in a conservative treatment, i.e. with a plaster of Paris, are used in a similar way. In this case, an interstitial tissue pressure can be monitored for a long time.

4. Conclusions

The methodology of principles and regulations of the measurement allowed us to prove correctness of the approximation process of invasive and non-invasive TP. On the basis of the above results, the application of sensors to the monitoring of TP changes was designed. Due to monitoring not only the time of the treatment was shortened, but also its course was substantially changed. The measurement has been applied in a traumatic surgery of the Teaching Hospital of Pasteur in Košice.

Acknowledgement

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