SECTION 23.
MEDICAL SCIENCES AND PUBLIC HEALTH

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DEALING WITH THE PRESSURE IN PNEUMATIC COMPRESSION THERAPY

Pressure level is one of the common parameters to describe the applied intermittent pneumatic compression (IPC) procedure due to the ease of measurement and its significant role in patient comfort and clinical efficacy. However the pressure level as a phenomenon is divided into several components, namely: formal pressure, actual pressure inside the chamber, pressure on the surface of the body, pressure propagating in soft tissues, and the perception of pressure by the patient. The purpose of this publication is to draw the attention of the practitioner to the peculiarities of understanding and applying these types of pressure.

Formal pressure, measured in mm Hg, is what the gauges on the control panels of the IPC devices show. It is this pressure that is described in scientific articles, indicated in manuals, guidelines and medical prescriptions. The main purpose of this conditional value is to serve as a starting point for indicating the level of compression in a particular patient, associating it with a guideline. This parameter is also useful for describing and comparing the devices. This means that the level of pressure we usually think of as acting on the patient during a procedure is schematic and idealistic.

Actual pressure inside the chamber. Some devices may not have a pressure gauge. In such devices, the pressure level in the pneumatic system is either not measured or is measured by surrogate units. This is not always convenient, but may be acceptable, since the formal pressure itself does not play a fundamental clinical role. The main pneumatic components of the IPC devices are shown in Figure 1.

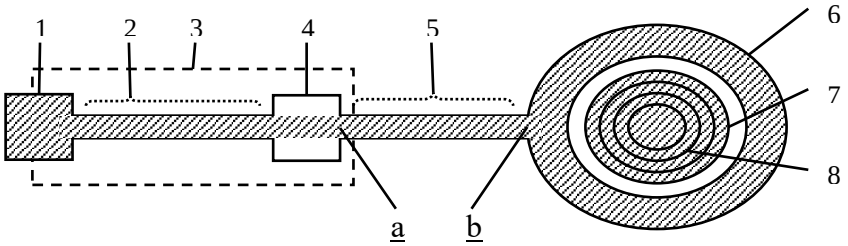

Fig. 1. **Scheme of the design of IPC devices. 1 – compressor; 2 – first air duct; 3 – device body; 4 – valve; 5 – second air duct; 6 – chamber; 7 – skin surface; 8 – soft tissue layers in the limb cross section; a, b – pressure control points (explanation in the text).**

Since the pressure gauge is built into the system no later (point a) than between the valve (4) and the second air duct (5), its data can be trusted if only it is assumed that the air pressure in the entire pneumatic system is the same. However, the inevitable losses, the material of the chamber (hard plastic, elastic rubber, etc.), the density of the fastener (tight, fitted or loose) and other features make their own amendments, difficult to control. The most accurate measurements are obtained by placing the pressure gauge at point b. When working with models of different manufacturers, we have found that the actual pressure is approximately 5 mm lower than the pressure indicated by the device. One of the models by Zemits [zemits.com] declared a pressure of 120 mm Hg on the monitor, while the actual pressure was 60-65 mm Hg. Based on the Hagen-Poiseuille ratio (1)

$$\Delta P = \frac{8\eta l Q}{\pi r^2} \quad (1)$$

the pressure difference between the manometer and the chamber always exists, it directly depends on the length of the duct l and is inversely proportional to the radius r^2 of the duct (chamber).

Pressure on the body surface. If the pressure in a pneumatic system can be measured with an aneroid sphygmomanometer, tensor sensors are needed to measure the pressure on the surface. These measurements revealed two effects:

1. The air pressure in the chamber is evenly distributed along the sectional perimeter of the limb. But due to the protruding parts of the body and the anatomical and mechanical heterogeneity of the tissues, the result is not uniform, and the greatest pressure is formed on the protruding areas.
2. The pressure on the surface can be either higher or lower than the pressure in the chamber [Lurie, 2008]. Apparently, this depends on the design of the cuff, the dimensions of the chamber, the tightness of the fastener, and other factors.

The traditional dosage of pressure remains the one in the chamber. Clinical "norms" of pressure on the surface are not defined and are currently of theoretical interest. In cases where local over-compression is undesirable, soft pads are used to smooth and dampen the action of the cuff.

Pressure spread in soft tissues is the goal of the whole procedure. This began to be studied in recent years by non-invasive (CT, MRI) and, in experiments, invasive methods, inserting microsensors deep into tissues. Unfortunately, only a few data have been received so far. It has been shown that external compression is almost completely compensated by the superficial fascia [Lurie, 2008]. But this effect may differ at different ages and muscle mass; cases of ischemia show that compression can also affect deep arteries. The pressure in the tissues is lower than the applied external pressure, and the local pathological stiffness of the tissues can be an important factor in the success of therapy [Zaleska, 2019]. There are also some reports that the pressure in the superficial layers may be less than in the depths of the tissues. The circumstances that make this paradox possible require clarification. The patterns of tissue compression created by manual massage are only partially applicable to IPC, since the surface area and the nature of movements are too different. Some computer models have been developed to explain and predict clinical effects, but their results still require caution.

Patient's pressure perception. Sensitivity is not only individual (congenital differences in the receptor apparatus), but also situational (acquired functional state of the receptors). Our studies [Зайцев, 2018] also suggest that the IPC procedure itself increases the effectiveness of afferent impulses. The difference of mechanoreceptors quantity in different areas of the skin is especially important with variability in the location of the chamber. So, how the patient feels external pressure is due to (asterisks indicate variable factors):

– individual sensitivity and its changes (hypo-, hyperesthesia, the action of neurotropic substances*), physique, topographic anatomy of the treated area*, skin temperature*, clothing*,

psychological attitudes (body feeling, subjective expectations*);

– cuff design (compression area) and material properties, method of its application (compression uniformity)*;

– procedure parameters: pressure level*, rate of pressure changes*, compression duration*.

It is important to remember that as the pressure in the cuff increases, the patient is less and less sensitive to the dynamics of the compression level (the Weber–Fechner law). We also believe that patients are more compliant to high pressure therapy, which can be explained both by the illusion of a direct dependence of the effect on exposure, and by the orientation towards proprioceptive comfort. Therefore, we cannot rely entirely on a self-report of patient feeling, even when providing the same prescription with the same device on the same zone.

Recommendations.

1. When putting a new apparatus into operation, if its design permits, check with a manometer the difference between the pressure on the monitor and the actual pressure in the chamber.

2. Use soft pads for more uniform compression, especially in patients with local tissue deficiency.

3. Further research on the spread of external pressure in soft tissues are urgently needed.

4. Although the subjective sensations of the patient must be taken into account (at least as far as they are related to compliance), they cannot be a trivial basis for pressure measurement.

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