A METHOD FOR THE COMBINED STUDY OF TEMPERATURE, PRESSURE, AND GASEOUS COMPOSITION OF THE SUBCUTANEOUS BULLAE FORMED IN HIGH-ALTITUDE TISSUE EMPHYSEMA

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When warm-blooded animals are raised to a height where the atmospheric pressure is less than 47 mm mercury, the little-known condition of high-altitude emphysema may develop. Its essential feature is that when the pressure falls below 47 mm mercury the tissue fluids boil at the body temperature of 37°, and in addition the gases dissolved in the tissues come out solution.

The external manifestations of high-altitude tissue emphysema are that for several seconds the skin separates as a layer and balloon-like swellings are observed on the body surface (Fig. 1).

The principal factors in the pathogenesis of high-altitude emphysema are temperature, pressure, and the gaseous composition of the subcutaneous bulla which forms as a balloon-like swelling of the body.

The method and experimental arrangement which we have proposed enables simultaneous observations to be made in a pressure chamber of temperature changes and pressure, and provision is made for the analysis of the gas from one of these bullae to be taken for analysis at any time.

The apparatus consists of a special combined needle, electrothermometer, rubber vacuum tubing with a three-way tap, a vacuum burette, mercury manometer, and kymograph (Fig. 2).

The combined needle was prepared from an injection needle (Fig. 3). At the end of the needle there is a thickening to which is soldered a side-piece (2) for the outlet of gas. The end of the thickened part of the needle is soldered into a cylinder (6) whose axis coincides with that of the needle. Within the cylinder there is a piston (4) most of which has the same diameter as the cylinder. This portion of the piston acts as a guide for movement along the cylinder and also acts as a shoulder as well as restraining the thermo-couple holder in the idle position. In the end of the piston there is an aperture with a groove. Into this aperture is introduced the thermo-couple holder with ebonite support (1) in which it fits tightly. In the face of the piston there are two pins, and to them are soldered leads from the thermistor and a wire running through the hole in the center of the piston and connected to the recording device. In the end of the cylinder there is a ring (7) which limits the movement of the piston when moved in the direction of the idle position of the thermistor. The ring serves to fix the device at the moment of action of the thermistor, because in it there is a channel through which passes the guide (5). When the force of the spring (9) is overcome the face of the piston to which is fixed a rubber covering (10) covers the needle. At this time the guide is free from the channel in the ring and is held by a small rotation of the piston to one side. At the end of the piston there is a head (8) having notches for convenience of operation.

When the needle is introduced subcutaneously the experimenter presses on the head of the piston so as to overcome the force of the spring; then he gives it a small rotation to maintain it in position. The thermistor emerges from the hollow of the needle, the cylinder is closed, and the gas passes through the side-piece.

The thermal element consisting of a thermistor is also mounted in the end of the neck of the needle, and after it has been introduced beneath the skin it can be moved over a distance of 1.5-2 mm. It is connected to an electrothermometer from which the temperature may be read directly or recorded graphically. For the measurement of pressure, in the channel of the needle between its walls and the projecting nipple to which it is fixed there is a gap which is in communication through a three-way tap with a manometer.

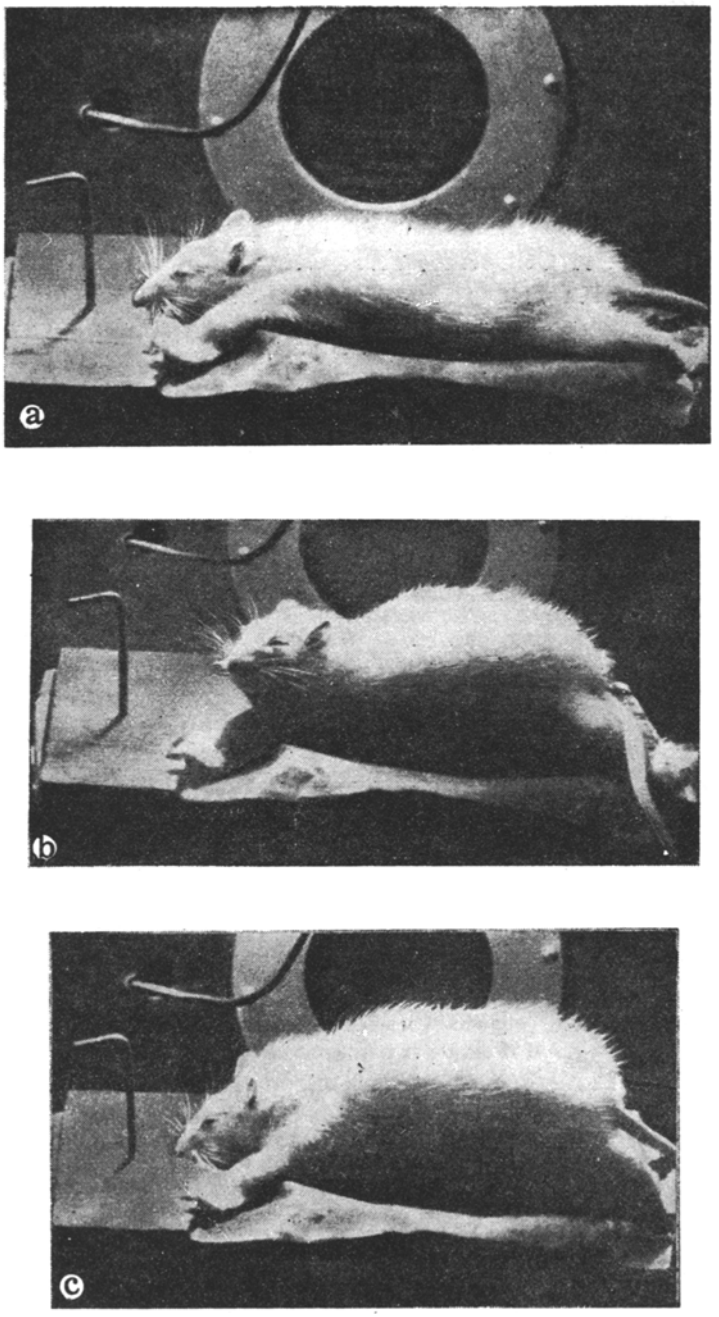

Fig. 1. External appearance of a rat (a) before rarefaction, (b) 20 sec, and (c) 50 sec after reduction of the pressure to 7 mm mercury.

Samples of gas are collected in a vacuum burette through the three-way tap. The whole apparatus, except for the electro-thermometer, is placed in a pressure chamber.

The method of operation is as follows. The animal is fixed in the prone position, and placed in the pressure chamber. The needle just described is inserted beneath the skin and the point at which it is introduced is carefully sealed with several layers of plaster and Mendeleev's paste. Then the unit carrying the temperature-sensitive element is pushed out and fixed in the operating position by rotation of the head.

Before the animal is raised effectively to a high altitude the three-way tap is moved into position II (see Fig. 2); in this position the needle is connected to the manometer and to the surrounding atmosphere. The animal is then

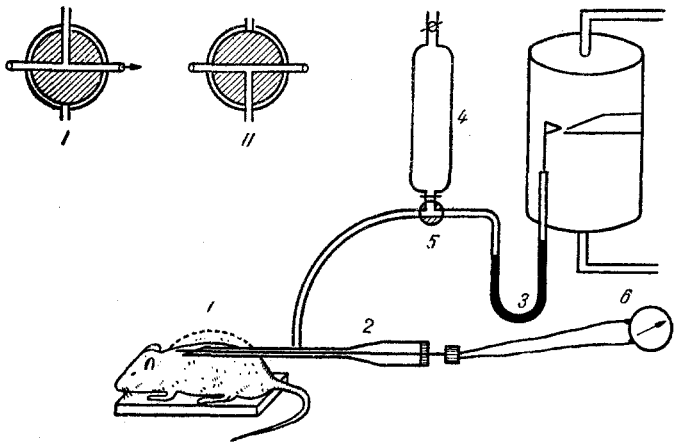

Fig. 2. Diagram of the apparatus for measurement of the temperature, pressure, and for the collection of gas samples from a bulla. 1) Rat; 2) combined needle; 3) manometer; 4) burette; 5) three-way tap; 6) galvanometer; I—tap connecting burette and manometer; II—tap connected to atmosphere.

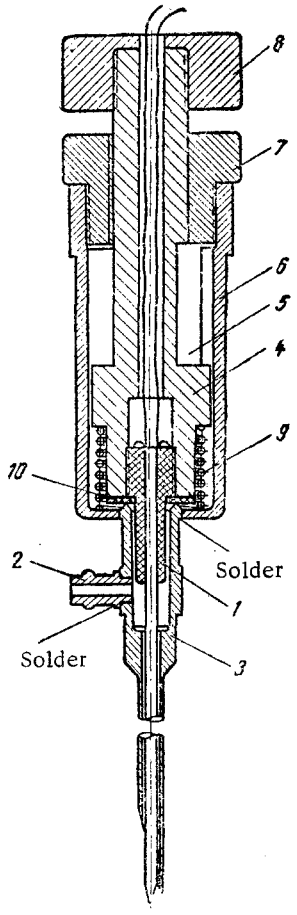

Fig. 3. Combined needle for the measurement of temperature, pressure, and for the collection of gas from a subcutaneous bulla formed by high-altitude emphysema (explanation in text).

effectively raised to a height at which the atmospheric pressure would be 47 mm mercury, i.e., less than the vapour tension of water at 37°. The ascent should be made by the method of "overfall" during 1-2 sec. During the rapid ascent the gases present in the manometer and in the rubber tube expand and enter the pressure chamber through one of the orifices of the three-way tap (position II). One or two seconds after the maximum height has been reached the three-way tap is moved into position I, and communication between the atmosphere and the pressure chamber is interrupted. In the subcutaneous bullae which have developed through high-altitude emphysema the pressure and temperature are recorded. Also at any moment a sample of gas may be taken into the burette for analysis.

The animals in which high-altitude emphysema has developed should not be kept at the high altitude for more than one minute, otherwise they may perish as a result of acute hypoxia. After a rapid descent to ground level the balloon-like swellings disappear, and the appearance returns to normal. Sometimes immediately after the descent respiration is arrested; it may be restarted by artificial respiration. After 15-20 min the animals cannot be distinguished from others which have not been effectively elevated.

In our work the experiments were carried out chiefly on rats, but the method described may be applied to rabbits, cats, and dogs. In these cases the needle inserted subcutaneously should be made somewhat longer (5-7 cm for dogs).

A simultaneous study for pressure and temperature in the bullae due to high-altitude emphysema shows that the gas pressure within the bullae may be maintained at a constant level not only on account of the vapour pressure but also because of the partial pressure of gases. The temperature within the bullae is reduced, but the expected reduction of vapor pressure does not occur because further supplies of gas from the tissues enter continuously*. A study of the gaseous composition and calculations of the gaseous composition and partial pressure show that the bullae receive not only water vapor but also the gases dissolved in the tissues, and that these gases assist in the separation of the layer of tissue and maintain the pressure in the bullae.

* E. A. Kovalenko and Yu. A. Yurkov, Patol. fiziol., 4, 26 (1961); 6, 11 (1962).

SUMMARY

This paper deals with the method of study of the three main factors concerned in high-altitude emphysema, namely temperature, pressure, and gaseous composition of the subcutaneous bullae. A new method is suggested which enables the investigations to be carried out by means of a needle containing a stylet thermotransducer, a set of vacuum burettes, a three-way tap, and a kymograph. Several experiments were carried out by this method at pressures down to 7 mm Hg. It was found that the temperature falls during the development of the bullae, whereas the pressure remains constant. The method may be applied to various species of animals.