USE OF ACTIVATED CHARCOAL FABRIC IN COMPOSITE DRESSINGS

T. S. Ustinova, R. I. Kaem,
A. V. Yanshevskii, and Yu. S. Lopatto

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In the production of composite dressings much attention has been paid to rendering the materials of the bottom layer atraumatic — capable of being removed painlessly and without trauma to the wound. However, atraumatic dressing with polymer membranes and metallized materials are insufficiently effective. Attempts have been made to use fabrics made from fibrous carbon adsorbents as coverings for the active treatment of burns and wound infection. These are interesting because in various kinds of exo- and endotoxicoses combined detoxication of the patient has been successfully accomplished with the aid of activated charcoal. Charcoal materials exhibit biospecificity of adsorption in relation to several physiologically active substances, tissue breakdown products, and microorganisms [4]. It has been suggested [3] that the diminution of edema, inflammatory processes, and toxic manifestations observed in experimental purulent wounds is due to the adsorbent activity of the charcoal fibers. The mechanism of action of charcoal-containing materials on wound healing has not been adequately studied, and this is also true of the reaction of charcoal fibers to contact with biological media. The adsorbent-diffusion properties of charcoal fibers must determine the functional characteristics of charcoal materials applied to burns and wounds — their detoxicating action, protection against infection, their atraumatic nature, and so on.

The aim of this investigation was a physicochemical and biological evaluation of activated charcoal fabrics (ACF) and to work out objective criteria for the selection of material for dressings.

EXPERIMENTAL METHOD

The aims were to study the atraumatic characteristics, wetting rate, and adsorbent capacity for water and blood, of therapeutic preparations and material in direct contact with the wound surface. The atraumatic properties were determined for samples soaked with blood (or albumin solution) on a model of a wound surface after drying at 37°C [5]. The adhesive strength (AS) of binding of the material with blood (or protein) was measured, and from the ratio of its values for surgical gauze and the test material, the atraumatic nature of the latter was evaluated as the index A:

$$A = \frac{\text{AS of surgical gauze}}{\text{AS of test material}} > 1. \qquad (1)$$

The greater than 1 the value of A, the more atraumatic the material. The hygroscopic properties of ACF were studied by adsorption gravimetric methods used previously [1, 2] to test absorbent dressing materials based on one-sided contacts of the specimen with a liquid medium or on water saturation of a vacuum-packed sample. Data in the literature obtained by the study of hemoperfusion were analyzed by adsorption of a model low-molecular-weight substance in order to determine its chemical state. We suggested such a method, based on measurement of adsorption of nitrofurazone, for the chemical structure of its molecules is similar to that of the so-called "average molecular weight toxins" and it exhibits chemical affinity for activated charcoal fibers. The concentration of nitrofurazone in the solution during adsorption was analyzed spectrophotometrically.

Laboratory of Dressing, Suture, and Polymer Materials in Surgery, Department of Pathological Anatomy, A. V. Vishnevskii Institute of Surgery, Academy of Medical Sciences of the USSR. Graphite Research Institute, Ministry of Nonferrous Metallurgy of the USSR, Moscow. (Presented by Academician of the Academy of Medical Sciences of the USSR D. S. Sarkisov.)
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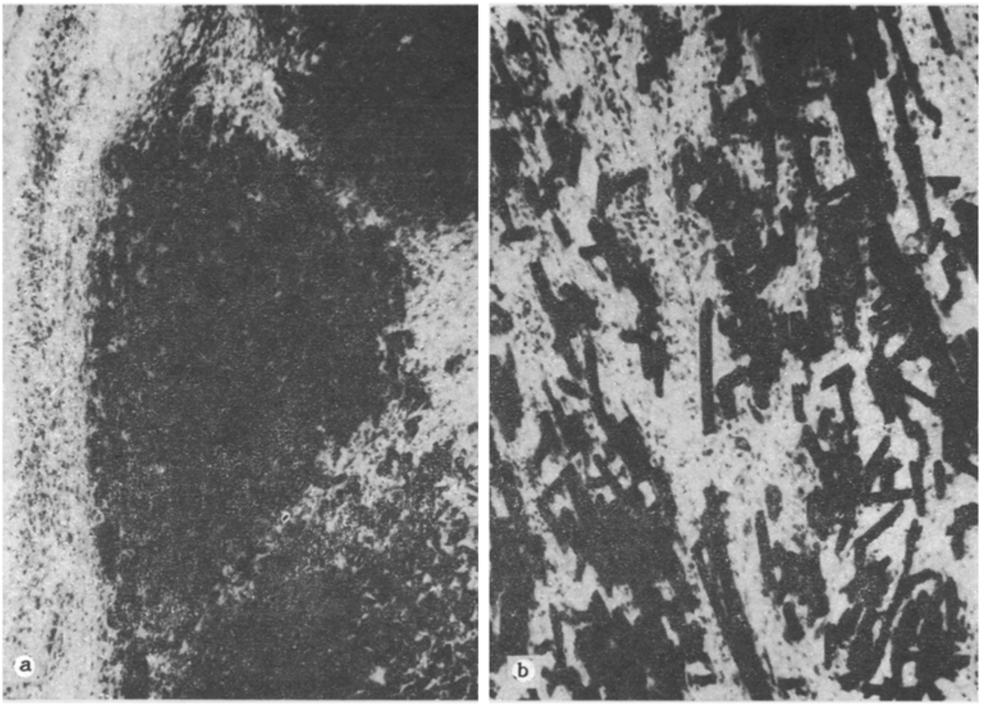

Fig. 1. Morphological changes in implanted ACF and tissue reaction to implantation. a) Seventh day of experiment. Unchanged ACF fibers, surrounded by a thin band of granulations, can be seen in the subcutaneous tissue; b) after 2 months of the experiment growth of young connective tissue can be observed between the relatively unchanged fibers, with capsule formation. 80 ×.

In a biological experiment samples of ACF were autoclaved and implanted in the subcutaneous aerolar tissue of albino rats (under ether anesthesia) for various times (up to 2 months). The local tissue reaction was studied with respect to the degree of inflammation and the character of formation of a connective-tissue capsule around the implant. Morphological changes in the skin and underlying tissue were investigated in sections stained with hematoxylin and eosin and with picrofuchsine by Van Gieson's method. The test objects were samples of graphited charcoal fabric produced by industry, from which the lubricant was removed, and the surface was activated to give it special properties.

EXPERIMENTAL RESULTS

The atraumatic index (A) of the charcoal fabrics was 2.5 ± 0.5 and was independent of the degree of activation of the samples. The lower value of adhesion of the charcoal fabrics to blood compared with cellulose material suggests that charcoal materials have a lower surface free energy and wettability with water [5]. The original charcoal fabric (without lubricant) was found virtually not to be wetted with water, unlike the activated samples, the wetting rate of which (about 10 sec) was the same as that of hydrophilic cellulose materials. ACF acquire wettability by aqueous media, evidently, because of the appearance of polar groups on the surface of the charcoal fibers, and their nature and concentration depend on the conditions of activation. The adhesion method of determination of atraumatic qualities is insensitive to the state of the surface of the charcoal fibers.

The adsorbent capacity of the samples relative to liquid media was 2.5 ± 0.2 g/g, which is several times lower than that for cellulose fiber materials, and is independent of the degree of activation of the charcoal fibers. The field of applicability of the adsorption methods used is confined to materials with a macroporous structure (with a pore diameter of the order of microns or more), for which the free volume of the pores is completely used during sorption. In charcoal fabrics with a dense structure there are few such pores and they are formed by capillary spaces between threads and fibers, for which the open porosity amounts to 80%, and after soaking with blood, only 66%. The system of micro- and mesopores charcteristic of charcoal fibers, and the chemical state of their surface, evidently cannot be assessed by traditional methods of testing absorbent materials. To assess the effectiveness of ACF in processes of adsorption detoxication, their adsorbent activity was determined relative to nitrofurazone molecules. It was found that ACF was appreciably better than surgical gauze as regards their capacity to adsorb nitrofurazone (2 mg/g for gauze), and that the nitrofurazone concentration in samples of charcoal fabrics was higher than in solution, unlike cellulose materals, in which it was the same as in solution. The reason is that adsorption of nitrofurazone on charcoal fibers is selective and takes place by a mechanism of activated diffusion, with gradual filling of increasingly inaccessible regions of the surface. Nitrofurazone molecules were not adsorbed on the original charcoal fabric, but with an increase in the degree of activation of the charcoal fibers adsorption increased, but only up to a certain limit. Later, besides chemical modification of the surface, destruction was intensified, with worsening of the functional properties of the material. The ability of ACF to adsorb and retain physiologically active low-molecular-weight substances determines their suitability for detoxication. This special feature of activated charcoal fibers ought to be manifested also on contact of the material with media of the living organism.

The morphological investigation showed that ACF implanted subcutaneously into animals did not evoke any marked inflammatory reaction. In the early period after implantation (until 7 days) concentrations of charcoal fibers, surrounded by a thin band of granulations, and with insignificant infiltration with lymphoid cells and polyblasts, were found in the substance of the subcutaneous tissue. Edema of the underlying muscle tissue was mild. On the 14th-21st day of observation concentrations of charcoal fibers were surrounded by a thin, delicate connective-tissue capsule, almost invisible under the microscope, and in some places the charcoal fibers were separated by proliferating fibroblasts. Young connective tissue, growing between the fibers 1 month after implantation, was in a state of maturation. Single multinuclear giant cells were seen in the cavity of the capsule. The morphological picture showed little change 2 months after implantation (Fig. 1).

The morphological investigation thus shows that ACF are resistant to the action of the media of the living organism. Much of the charcoal fabric was encapsulated with the formation of a thin connective-tissue capsule, and only a small part of it was invaded by connective tissue, breaking it up into separate charcoal fibers.

This investigation shows that ACF are promising materials for use in composite dressings, and the adsorbent activity of charcoal fibers with respect to low-molecular-weight physiologically active substances of a certain nature may be used to evaluate their surface properties and also as a criterion for choice of charcoal material for use in the treatment of burns and wounds.

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