accumulation, serotonin analogs, and so on, as antiarrhythmic agents [2]. Thus the principle of stimulation of stress-limiting systems of the body has definite prospects for practical use in cardiology.

LITERATURE CITED

1. G. N. Kryzhanovskii and Yu. I. Pivovarov, Byull. Éksp. Biol. Med., No. 5, 26 (1982).
2. F. Z. Meerson, Stress-Limiting Systems of the Body and Protection against Cardiac Arrhythmias [in Russian], Orenburg (1986).
3. F. Z. Meerson, The Physiology of Adaptive Processes [in Russian], Moscow (1986), p. 521.
4. J. Lepran, M. Koltai, W. Siegmund, and L. Szekeres, J. Pharm. Methods, 9, 219 (1983).
5. G. Manning, C. McEachern, and G. Hall, Arch. Int. Med., 64, 661 (1939).
6. J. E. Skinner, Stress and Heart Disease, eds. R. Beamich et al., Kluwer-Academic Boston (1984), pp. 44-59.
7. E. Stone and J. Platt, Brain Res., 237, 405 (1982).

ACOUSTIC RESISTANCE OF ADIPOSE TISSUE AS A PARAMETER OF ITS FUNCTION

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The view that adipose tissue is a metabolically inert variety of connective tissue has been revised in recent years. Fat cells have been shown to be derived not from connective tissue, but from special primary fat cells. Adipose tissue as a whole is characterized by metabolic activity which is controlled by neurohumoral regulatory mechanisms [5]. Besides supplying energy, adipose tissue performs the role of mechanical buffer and heat insulator in the body, so that its contribution to the vital functions is even more important. However, at least so far as white adipose tissue is concerned and, in particular, when it is compared with the other tissues of the body, this opinion is not universally shared. In my own opinion this is partly due to the inadequate sensitivity of traditional methods used to study adipose tissue.

The author has made an ultrasonic study of adipose tissue under normal conditions and in various pathological processes. The aim of the investigation was to obtain acoustic parameters of pathologically changed adipose tissue, which can be used to develop technical systems for ultrasonic diagnosis. Data on acoustic parameters only of normal adipose tissue have been published [6]. They are used for intravital ultrasonic measurement of the thickness of the subcutaneous fat layer in animals [4] and man [1]. This defect limits the differential diagnostic potential of ultrasonic systems for visualization of the internal organs and, in particular, of acoustic computer-assisted tomographs.

EXPERIMENTAL METHODS

The main group of experiments was carried out on 113 segments of adipose tissue of the omentum, mesentery, breast, lipoma, intermuscular fat, and subcutaneous fatty areolar tissue, freshly removed during operations on adult men and women. The method of ultrasonic reflectometry was used, by which the acoustic resistance (AR) of areas of tissue at the point of contact with a standard medium, was used. Full details of the acoustic part of the technique were described by the writer previously [3]. Contact was created between the tissue and the tip of an ultrasonic transducer, 5 mm in diameter. The material of the tip and the transducer as a whole can be cold-sterilized in disinfectant solutions. The error of measurement of AR did not exceed 0.8%. Values of AR of the tissue were averaged over the area of contact. The distance between the regions of tissue investigated was 1 cm. The surface param-

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TABLE 1. AR of Adipose Tissue Depending on Its Biological State (M ± m)

Histological characteristics of tissue	AR, MPa·sec/m	
	in tissue section	at edge of tissue
Normal (158)	1,325±0,001	1,325±0,001
Lipoma (20)	1,325±0,004	1,460±0,016
Acute inflammation (196)	1,405±0,002	1,450±0,003
Chronic inflammation (136)	1,560±0,004	1,650±0,003
Metastasis of medullary carcinoma (62)	1,515±0,004	1,525±0,004
Metastasis of scirrhus carcinoma (37)	1,650±0,006	1,665±0,006

Legend. Number of regions of tissue studied given in parentheses. Differences horizontally, except normal tissue and both types of carcinoma, are significant ($p < 0.001$). Differences from normal also significant, except for lipoma in section ($p < 0.001$).

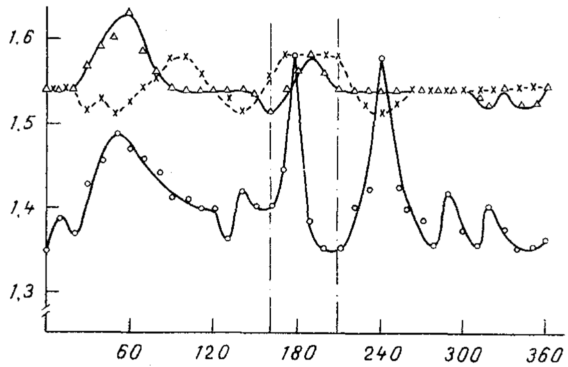

Fig. 1. Topography of AR values along a segment of small intestine resected on account of strangulated hernia. Abscissa) distance (in mm); ordinate) value of AR (in MPa·sec/m). Afferent segment of intestine on left, efferent on right. Two vertical lines indicate boundaries of zone of strangulation. Circles) omentum; crosses) mucosa; triangles) seromuscular coat.

eters of native adipose tissue were compared with bulk parameters, obtained after cutting the tissue. The state of the tissue in the regions investigated was monitored by a histological method (staining with hematoxylin and eosin and by Van Gieson's method).

EXPERIMENTAL RESULTS

As Table 1 shows, the average AR of normal adipose tissue is 1.325 ± 0.001 MPa·sec/m, and is independent of the conditions of measurement. This value agrees with data in the literature [6] obtained during postmortem investigations of normal adipose tissue by ultrasonic methods. We describe these values of AR as applying to "steady-state" or "resting" adipose tissue. Its acoustic properties are determined almost entirely by the lipid components and they are independent of age and sex. We found no mention in the literature of any such differences likewise.

For lipomas, as would be expected, in most regions of the section through the tumor tissue AR was the same as AR of "steady-state" adipose tissue. An increase in AR was found on the surface of the tumor, and the closer the region concerned to the edge of the benign neoplasm — the outer surface of the pseudocapsule — the greater the increase in AR. This rule can be explained chiefly by the reduction or almost total disappearance of the lipid content of this tissue at its boundary. Of all the components of soft tissues, it is fats which have the lowest AR [6]. The range of change of AR on the surface of the tumor is wider than in its bulk. We attribute this fact to the properties of the measuring technique. The shallow depth of the tissue layer subjected to ultrasonic probing means that acoustic changes can be recorded also in nonlipid regions of the tissue, which are characterized by the greatest reactivity.

During inflammation AR of adipose tissue also is increased, and the more marked the inflammation the greater the degree of its increase (Table 1). However, structural changes determining the increase in AR differ significantly for different stages of the inflammatory process. In acute inflammation the increase in AR is due mainly to an increase in tissue hydration on account of hyperemia, exudation, and other acoustically similar processes. For comparison, values of AR are given for water (1.49 MPa·sec/m) and blood (1.61 MPa·sec/m) [6]. In the late stages of inflammation resorption of lipid inclusions and intensification of collagen and fibril formation are observed [2]. These processes determine the increase in AR of adipose tissue up to the highest possible level. We know from bioacoustics that of all the organic components of soft tissues of the body collagen has the highest AR.

Changes in AR of adipose tissue in malignant processes are nonspecific (Table 1) and are due to the overall chemical changes in the tissue regions studied. This is confirmed by morphometry of the microscopic pictures which we carried out in some cases. It will be noted that differences in AR at the edge and in the section of the tissue are not significant in carcinoma, and this can easily be explained by infiltrative growth of the tumor, the absence of a pseudocapsule around it, and the absence of regions macroscopically demarcated from the surrounding tissue.

No significant differences in AR of adipose tissue depending on age and sex could be found under both normal and pathological conditions, although a small decrease in this parameter was noted in the breast tissue of young women with mastopathy.

Reactive changes recorded by means of ultrasound in adipose tissue cannot be separated from measurements in its connective-tissue components because of the conditions of measurement. However, there is no need for this, evidently, for these components constitute a morphological and functional entity together with adipose tissue, which must be manifested during reactive tissue processes. This single mechanism of function is most clearly reflected, in my opinion, in the patterns of topography of AR of adipose tissue, a characteristic feature of which is the smoothness of the changes in value of AR and the long-distance correlations (Fig. 1). Under these circumstances significant differences of AR were found within regions of normal adipose tissue with a histologically uniform structure. Such changes can be conventionally described as functional, or linked with latent phases of a pathological process [7].

Distinct patterns of topography of AR of adipose tissue, reflecting the histotopography of the pathological process in the region tested, were observed in all parallel measurements of AR of adipose tissue and the adjacent regions of the internal organs (Fig. 1). Acoustic reactive changes in adipose tissue were shown to be more marked always than in muscular and glandular tissue.

All the results described above apply equally to the living organism. This was confirmed by comparing them with the results of preliminary measurements actually inside the operation wound (28 operations).

A disturbance of AR of adipose tissue was thus demonstrated in pathological processes. These disturbances are well-marked on the surface regions of the tissue. An increase in tissue AR reflects the degree of development of reactive changes in it in response to pathological processes. Acoustic changes in the adipose tissue of an organ are more marked than in muscular and glandular tissue, further proof of the high functional activity of this tissue.

LITERATURE CITED

1. R. N. Bolkhovskikh and Ya. M. Kots, Teor. Prakt. Fiz. Kul't., No. 12, 66 (1972).
2. E. V. Dmitrieva, Arkh. Anat., No. 10, 37 (1968).
3. P. O. Lipovko and V. M. Lubé, Akust. Zh., No. 1, 359 (1981).
4. I. A. Mulyar and P. E. Ladan, Sb. Nauchn. Tr. Donskoi Skh. Inst., 4, No. 2, 8 (1968).

5. E. Newsholme and C. Start, Regulation in Metabolism, Wiley, London (1973).
6. L. S. Persianinov and V. N. Demidov, Ultrasonic Diagnosis in Obstetrics [in Russian], Moscow (1982).
7. A. Policard, Inflammatory Reactions and Their Dynamics [Russian translation], Novisibirsk (1969).