HEMODYNAMICS AND OXYGEN BALANCE OF THE RAT UTERUS

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The oxygen balance of the uterus at different stages of the reproductive process has not been adequately reflected in the literature. Nevertheless, its urgent importance is obvious because maintenance of optimal oxygenation of the intrauterine fetus is a vital condition for its normal development.

The writers showed previously in a polarographic study that a periodic fall of pO_2 followed by restoration of its initial level takes place periodically in the tissues of the myometrium in animals of different species, either not pregnant or at different times of pregnancy. The cycles thus discovered were conventionally described as hypoxic. It was found that their frequency and the amplitude of pO_2 fluctuations differed in different species and also at different phases of the generative process, but the existence of hypoxic cycles has invariably been confirmed [10]. It has been suggested that their nature is linked with spontaneous rhythmic contractions of the uterine blood vessels [3].

The aim of this investigation was to study the architectonics of the vascular bed and the hemodynamics in the broad ligament of the uterus (BLU) of nonpregnant rats, which contains the extramural part of the vessels supplying the uterus with blood.

EXPERIMENTAL METHOD

Experiments were carried out on 30 nonpregnant rats weighing 150-200 g, anesthetized with pentobarbital (50 mg/kg). A biomicroscopic study of the architectonics of the vascular bed of BLU and of the microcirculation in it was carried out on a special apparatus mounted on the MBI-15 microscope, and equipped with a thermostatically controlled stage, with a light guide. In the course of visual observation of the microcirculation, responses of the microvessels were studied by morphometry, photography, and chronometry.

EXPERIMENTAL RESULTS

One of the principal features distinguishing the architectonics of the vascular bed of this region is the larger number of small arteries than of veins, yet despite this, the capacity of the venous part is much greater than the capacity of the arterial part, due to the abundance of vessels with storage and by-passing functions and also the much greater diameter than usual of the large venous trunks compared with arterial (the ratio between them is 4:1; for comparison, in the mesentery of the small intestine it is 2:1). Thus the vascular territory of the BLU has features of a storage network. The terminal part of the vascular bed has the most complex structure. It combines features of classical and bridge types with great diversity of intervascular communications, responsible for the high adaptive capacity of the circulation. Yet another important feature of the architectonics of this region is the helical shape of the resistive vessels, which in our view is an important biomechanical adaptation, maintaining an increased resistance in this part of the extramural uterine circulation. Similar features of organization of the vascular bed were found by other workers in other female reproductive organs – in the uterus and uterine tubes, and in the ligamentous system

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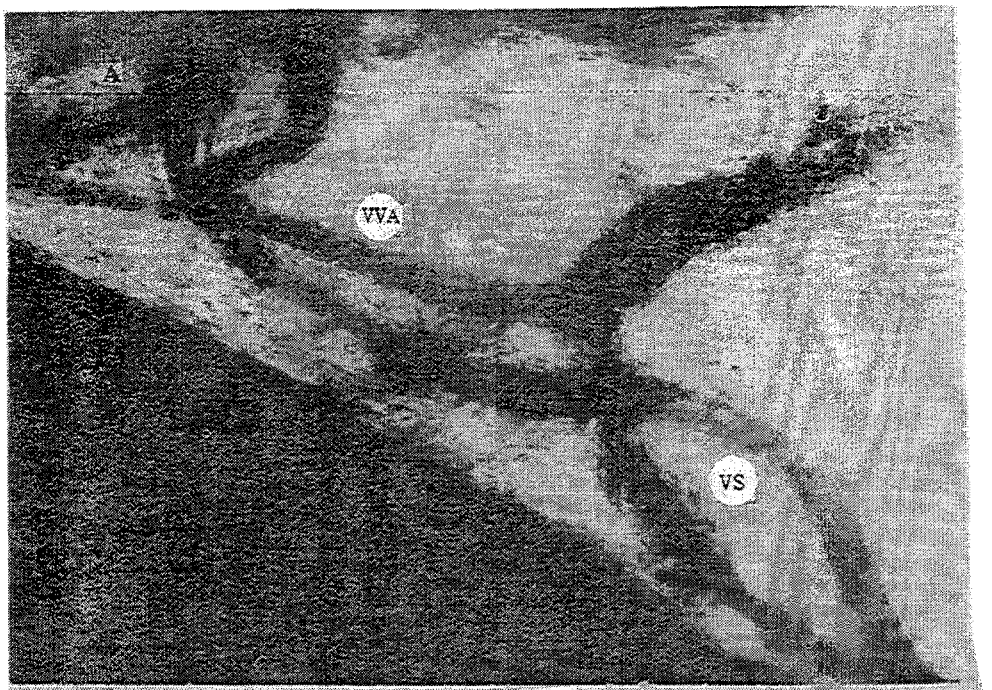

Fig. 1

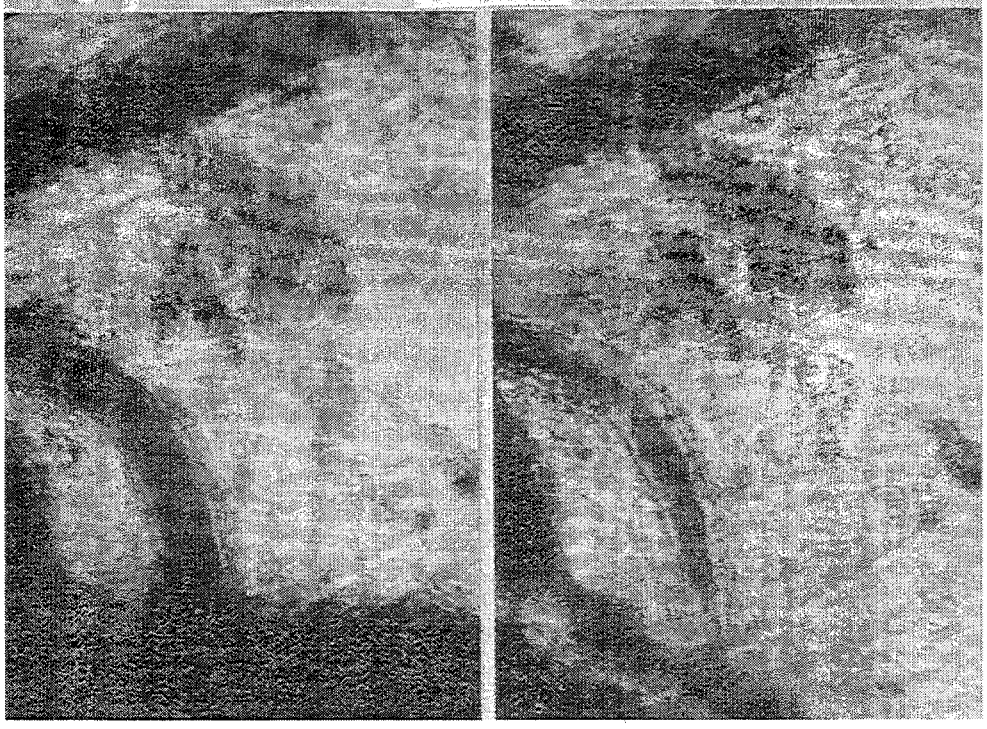

Fig. 2 Fig. 3

Fig. 1. Architectonics of vascular bed of BLU: helical shape of artery (A), venous sinus with sphincter (VS), and venulo-venular anastomoses (VVA).

Fig. 2. Phase of intensive blood flow in artery storing blood in sinus.

Fig. 3. Phase of reduction of blood flow in artery, irregular constriction of its lumen. Photomicrograph, 100×.

[1, 2, 5, 7, 8]. This suggests that these features are specific for this particular system, and formed during evolution in order to support the reproductive function.

Observations oriented on the hemodynamics in the region of the mesenteric edge of the uterine cornu, where the main part of the microcirculatory bed is located, revealed a number of specific features characterizing the microcirculation of this region. The arterial part of the vascular bed here consists of helical arteries, whereas the venous part includes muscular venules, storage vessels of sinusoid type, equipped with proximal and distal sphincters, and arteriolo-venular and venulovenular anastomoses (Fig. 1). A study of the character of the blood flow revealed rhythmic changes which were manifested most clearly in the helical arteries. Four phases of each cycle of this biorhythm could be identified: phase I – dilatation of the artery, rapid blood flow in it (Fig. 2); phase II – irregular constriction of the artery, a slow and intermittent type of blood flow in it (Fig. 3); phase III – complete closing of lumen in a certain part of the artery, cessation of the blood flow below, and retrograde movement of blood above the closed lumen of the vessel; phase IV – gradual opening of the arteriole, resumption of the blood flow in it (Fig. 1). The duration of the full vascular cycle in rats in different phases of the estrous cycle differed. The most marked but shortest changes in blood flow were observed during estrus. The frequency of the vascular cycles observed varied from 0.2 to 2.0/min, in agreement with the frequency of cyclic fluctuations of pO_2 which we discovered previously in the myometrium [10]. This suggests that rhythmic changes in the hemodynamics found in the extramural vascular bed of the uterus and hypoxic cycles in the myometrium are interconnected and, consequently, a rhythmic fall of pO_2 in the myometrium of the uterus is hemodynamic in nature. The discrete character of the blood flow in both nonpregnant and pregnant rats, on biomicroscopic investigation, was found by other workers also in the serous membrane of the uterus [4, 9] and actually in the myometrium [6]. This shows that the particular feature of the hemodynamics found in BLU also reflects the specific nature of the uterine circulation.

The cyclic character of the blood flow in the venous cycle of BLU was smoother in nature, due to the fairly complex redistribution of blood between its component parts. In the phase of complete closing of the helical arteries, the extramural storage venous sinuses began to fill, and this was accompanied by delay of drainage of the venous bed. Maximal storage of blood took place in phase II, when the inflow along the helical arteries began to slow down. In the phase of minimal blood flow in the arteries (the hypoxic phase) a revival of drainage was observed, accompanied by an increase in muscle tone of the extramural veins and a reciprocal reduction of tone of the sphincters. With resumption of the blood flow in the helical arteries a fresh decrease in the drainage function and increase in the storage function of the venous part of the vascular bed of BLU were again observed. The particular features of the architectonics and hemodynamics found in the circulatory system of BLU thus characterize this structure as a vascular basement with a marked storage function. Cyclic circulatory hypoxia, caused by the rhythmic and discrete character of the blood flow in the arterial bed, was linked with cycles of storage and drainage of blood in the venous bed, when the intensity of the storage function exceeded that of drainage. The intermittent character of the blood flow in BLU reflects the corresponding specific feature of the hemodynamics of the uterus and of the intrauterine fetus, which share the same circulatory system. We regard the hypoxic cycles thus revealed as a physiological mechanism, consolidated by evolution, for the supply of materials for the cyclically proliferating mucous membrane of the nonpregnant uterus, and also for hypertrophy of the uterus and growth of the interuterine fetus during pregnancy. These hypoxic cycles are at the same time a mechanism of the increase in resistance of the fetus to hypoxia during pregnancy, during delivery, and in the early neonatal period.

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