THE COLLECTOR SYSTEM OF THE THYMUS

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UDC 612.438:612.13.014.2+611.438:611.13/.14

KEY WORDS: thymus; tissue-blood barrier; blood stream.

Despite intensive study of the physiology of the thymus, some structural units of this organ have not yet been investigated. In particular, the character of the structure of the vascular system of the thymus, participating in the formation of the tissue-blood barrier, which is responsible for differential migration of lymphocytes into the blood stream, has not been completely elucidated. The structure of the vascular system is known to reflect the particular features of the physiology of organs, and for that reason the results of its study, in turn, can facilitate an understanding of some aspects of the function of an organ. The thymus of man and some other mammals is supplied by branches of the internal mammary artery [1, 12]. Dividing into very small branches, the blood vessels diverge along the interlobular septa. If the arterial network is injected with Prussian blue, a dense network of unbranched vessels running from the interlobular connective tissue perpendicularly to the surface of the lobule, through its cortical zone, and cut off in the corticomedullary zone, can be seen [4]. Histologically, thin, radially arranged vessels can also be observed in the cortical zone. In the medullary zone most of the vessels which can be seen are main branches passing through. The ultrastructure of the walls of the blood vessels of the thymus at different levels of the lobule has been well studied [13]. The vessels of the cortical zone have been shown to have a dense, relatively impermeable basement membrane; in capillaries of the corticomedullary zone the membrane is rather loose and lymphocytes can pass easily through it into the blood stream. In a previous study [3] a dense argyrophilic stroma was revealed in the walls of the radial vessels of the cortical zone by impregnation with silver.

The aim of this investigation was to discover the microcirculatory system of the thymus responsible for differential migration of lymphocytes from the gland into the blood stream.

EXPERIMENTAL METHOD

The thymus glands of five guinea pigs weighing 200 g were studied. The animals were killed under ether anesthesia. Pieces of the tissues were placed in 12% neutral formalin for 7-10 days. After thorough washing of the fragments in running water, sections 30-80 μ thick were cut on a freezing microtome. The blood vessels of the microcirculatory system were visualized by impregnation with silver by the Rasskazova–Kupriyanov method [7].

The order of treatment of the sections was as follows: tap water 2 h, distilled water and 60% ethyl alcohol 30 min, distilled water 3 min, 20% $AgNO_3$ at 37°C 1 h, 1% formalin (four or five successive portions until the solution was clear), 20% ammoniacal silver 3 min (the sections were first dried with filter paper), 0.5% formalin (the section becomes brown in color), ammonia water 1:2 (rinse). Next, the sections were dehydrated in the usual way and mounted in balsam under a coverslip. Some sections, 10-15 μ thick, were stained with hematoxylin and eosin as the control.

EXPERIMENTAL RESULTS

In thin sections (10 μ) stained with hematoxylin and eosin the guinea pig thymus had its characteristic appearance. The cortical zone was rich in lymphoid cells, but only a few

Laboratory of Streptococcal Infections, N. F. Gamaleya Institute of Epidemiology and Microbiology, Academy of Medical Sciences of the USSR, Moscow. (Presented by Academician of the Academy of Medical Sciences of the USSR P. A. Vershilova.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 92, No. 9, pp. 371-373, September, 1981. Original article submitted February 2, 1981.

0007-4888/81/9209-1287$07.50

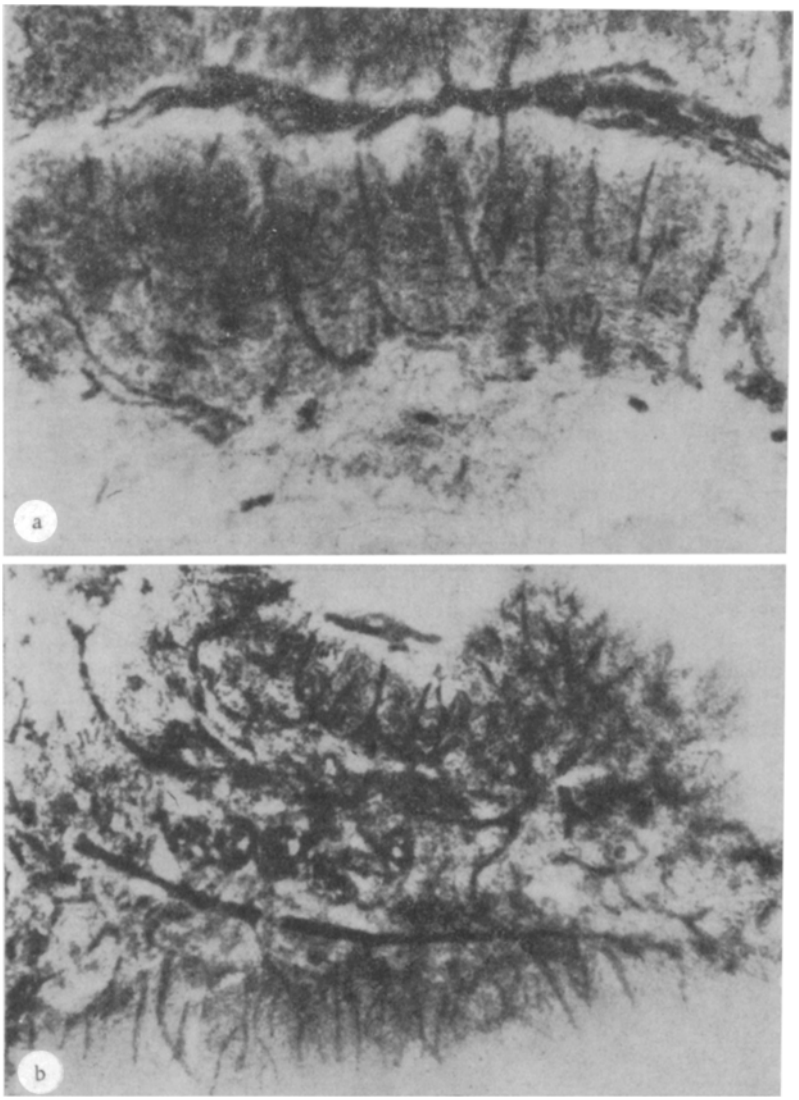

Fig. 1. Section through guinea pig thymus 50 μ thick: a) cortical zone: numerous arcs of microcirculatory network of blood vessels of collector system can be seen, 160 ×; b) medullary zone: main branches run through it forming virtually no anastomoses with arcs of cortical zone, 90 ×. Impregnation with silver by Rasskazova—Kupriyanov method.

lymphocytes were present in the medullary zone; typical lamellar epithelial corpuscles were present. The vessels of the cortical and corticomedullary zones appeared as short fragments or in cross sections. As a result of impregnantion of thick sections (30-80 μ) with silver by the Rasskazova—Kupriyanov method, blood vessels of widely different calibers could be seen in the thymus. In the interlobular connective tissue some quite large branches of the arterial and venous network of the thymus were impregnated. In the area of the lobules much thinner vessels could be seen, forming its microcirculatory network. Many thin unbranched vessels penetrated through the basement membrane perpendicularly to the surface of the lobules into the cortical zone from the interlobular tissue. Having passed through the cortex of the lobule they formed an arc in the corticomedullary zone and turned back into the interlobular tissue (Fig. 1a). In one section through a lobule of the thymus, 30-80 μ thick, there were 20-30 such arcs (or loops), constituting the microcirculatory network of the cortical zone. These arcs anastomosed only infrequently with one another. A section through one limb of the arc (venule) was larger than the other limb (arteriole). The limb of the arc running along the corticomedullary zone and forming the vault of the arc was impregnated rather less strongly than the rest, and in its morphology

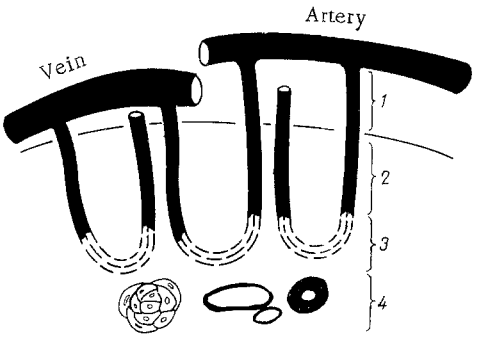

Fig. 2. Scheme of collector system of thymus responsible for migration of mature T cells from the thymus. 1) Interlobular tissue; 2) cortex; 3) cortico-medullary zone; 4) medullary zone.

it could only be described as a blood capillary. The difference in structure of the different components of the arc was particularly clearly visible under high power (400 ×). Neither the point of branching of the arterioles from the arteries of the interlobular septa nor the point of entry of the venules could be identified. The vascular network of the cortical zone of the guinea pig thymus is shown schematically in Fig. 2. In the medullary zone there were few vessels, only single main branches, with a larger cross section than the vessels of the cortical zone (Fig. 1b). These vessels, as they passed through, gave off hardly any branches and formed virtually no anastomoses with the arcs of the microcirculation of the cortical zone. They gave off a few small branches in various parts of the medullary zone.

To sum up the data obtained by various methods, showing that the radial blood vessels of the cortical zone have a well defined basement membrane [13] and a dense argyrophilic basis of their wall [3], and also the fact that a basement membrane is present, separating the parenchyma of the gland from the tunica adventitia of the vessels [9], the view must be accepted that a sufficiently strong tissue-blood barrier is present in the thymus [6, 14]. However, this barrier has a strictly local character and is typical only of the cortical zone of the thymus; for the walls of the blood capillaries in the corticomedullary zone, as shown by ultrastructural analysis, have a loose membrane, readily permeable for lymphocytes [13]. Precursors of T cells are known to pass from the lymphatics of the interlobular septa through the outer basement membrane into the peripheral zone of the cortex of the lobule [11]. There the lymphoblasts begin to proliferate and thymocytes begin to differentiate under the influence of the many different factors of the epithelial tissue of the thymus [2, 5, 8, 10, 15]. Since under normal conditions immature lymphoid cells cannot migrate into the blood stream because of the existence of the local blood-thymus barrier, and since differentiated cells can leave the organ freely, it can be concluded that the microcirculatory network of the thymus plays the role of collector system of the gland, responsible for liberating mature T cells into the blood stream. A disturbance of the permeability of the vessel walls in the cortical zone in the case of development of a pathological process must be accompanied by the liberation of some immature T lymphocytes into the blood stream. Since the capillary network in the medullary zone is poorly developed, some accumulation of mature T cells takes place there. The medullary zone of the lobules in that case plays the role either of a storehouse of mature cells or of a zone where the T cells migrate if they do not enter the capillary lumen. The first hypothesis seems less likely because under normal conditions no large accumulation of lymphocytes (such as are characteristic of depots) are found in the medullary zone of the lobules.

A certain time during which lymphocytes are present in the internal medium of the thymus is thus evidently necessary for contact between lymphocytes and the many differentiation factors of the gland, responsible for maturation of T cells, and this is ensured by the existence in the cortical zone of a strong local tissue-blood barrier and a collector system of blood vessels.

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GENESIS OF THE GOLGI COMPLEX

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UDC 576.311.335

KEY WORDS: Golgi complex; genesis.

The reality of existence of the Golgi complex is no longer in doubt [5, 9, 14, 15], but the problem of its origin has not yet been finally solved. According to one view, elements of the Golgi complex arise from cisternae of the rough endoplasmic reticulum (RER) by budding from the smooth-surface regions of the membranes and conversion into Golgi membranes [10]. The functional continuity between the endoplasmic reticulum and Golgi complex has been demonstrated autoradiographically and histochemically [7, 11]. In studies on lower organisms, the cells of insects, and certain tissues of higher animals, it has been postulated that the Golgi complex originates from the outer nuclear membrane [8, 12, 13]. The object of this investigation was to study the sources of origin of the Golgi complex in cells during ontogeny.

EXPERIMENTAL METHOD

The ultrastructure of hepatocytes of rats during embryonic (daily from the 13th through the 21st days) and postnatal (1, 4, 14, and 30 days after birth) ontogeny, and of chick embryos from the 6th day of incubation until hatching, was studied. Liver tissue was fixed by Palade's method at pH 7.2-7.4 and embedded in Araldite. Ultrathin sections were stained by Reynolds' method and investigated in the HEM-7A electron microscope.

EXPERIMENTAL RESULTS

On the 13th, 14th, and 15th days the Golgi complex in the cytoplasm of the embryonic rat hepatocytes was in the immediate vicinity of the nucleus. On the 13th day of embryonic

Laboratory of Evolutionary Histology, A. N. Severtsov Institute of Evolutionary Morphology and Ecology of Animals, Academy of Sciences of the USSR, Moscow. (Presented by Academician of the Academy of Medical Sciences of the USSR V. I. Struchkov.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 92, No. 9, pp. 373-376, September, 1981. Original article submitted March 25, 1981.

 0007-4888/81/9209-1290$07.50