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Research Article

The Ratio of the Thickness of Myelin Sheath of the Axon to its Diameter in Nervous Fibers of the Musculocutaneous Nerve in the Prenatal Ontogenesis

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Abstract

Performing an insulator function, the myelin sheath covers the axon, which is involved in conducting a nerve impulse. In the course of some research, great attention was paid to the relationship between the thickness of myelin sheath of the axon and its diameter and there were the statements of contradictory opinions. The purpose of the study is evaluation of the ratio of the thickness of myelin sheath of the axon to its diameter in nervous fibers of the musculocutaneous nerve in the prenatal ontogenesis. The pieces of the musculocutaneous nerve in 6 - 9 month old fruits a length of 63 mm and a length of 10 mm were got. The principles of the structure of myelinated fiber for all stages of prenatal ontogenesis are the same and in a full-term newborn the growth of common myelinated fiber occurs due to thickening of the myelin sheath and the growth of the axial cylinder. Between of the thickness of the myelin sheath and the diameter of the axial cylinder there is a straight line correlative relationship. In some cases, there are discrepancies in the general pattern: fibers with a thin myelin sheath have axons with large diameters or vice versa. This is a characteristic feature of the fibers in the earlier stages of the process of myelination and associated with preservation of cytoplasmic structures between the layers of lipoprotein plates.

Keywords: *Musculo-Cutaneous Nerve; Axon; Myelin Sheath*

Introduction

Features of the formation of nerve fiber and its components, that is, the myelin sheath and axon, are in the field of research work by neuromorphologists and neurophysiologists [1-6]. Despite the fact that the first information about myelin fibers was reflected in the works of the authors of the 19th century, the data on their myelinization belong to the 20th century [7-9]. Electron microscopy materials should be taken shortly after death. Because of this, the main ultrastructural studies were conducted on animals [8,10-12] or on their embryos [7] and in isolated cases, on humans [13-16]. In some of these works, much attention was paid to the ratio of the myelin sheath to the axon and conflicting opinions were expressed [8,17-19]. Performing an insulating function, the myelin sheath covers the axon, which is directly involved in the conduct of a nerve impulse. In this regard, the authors' opinion that myelination occurs in a non-specific way under the influence of axon pressure on the myelin sheath deserves special attention [8,18].

Purpose of the Study

Under an electron microscope, study the ratio of the thickness of the myelin sheath to the axon diameter of the fibers of the musculocutaneous nerve in prenatal ontogenesis.

Materials and Methods

In 6 - 9-month-old fetuses, the musculocutaneous nerve was examined in two areas: in the proximal part, before entering the coracobrachial muscle, and in the distal part, at the beginning of the lateral antebrachial cutaneous nerve. In the proximal part, the nerve consists of fibers intended for innervation of muscles and skin, and in the distal part, for innervation of only the skin and its derivatives. Pieces of muscular-cutaneous nerve in the amount of 63 and a length of 10 mm were taken within 90 minutes after death. After 1 - 2 hours, nerve samples are cut. Samples of 1 mm^3 in size continued to be fixed in a 2.5 - 5% glutaraldehyde solution in phosphate buffer. After washing in three shifts with an interval of 10 minutes, pieces of material were fixed in a 2% OsO_4 solution. Later blocks nervous were received. Slices were obtained on a Reichert-Iung and LKB-4800 ultra-microtome for viewing on a JEM-100S, JEOL-100S electron microscope. First, we made semi-thin sections (1.0 μm) for orientation, they were pre-stained with tululoid blue. Ultrathin sections 20 - 30 nm thick were obtained from the remaining blocks. Sections for a small increase were relatively thick. Sections were contrasted with a 2% aqueous solution of uranyl acetate and lead citrate according to the Reynolds method. The image of the object was recorded on a photographic plate at a direct magnification of 2000 - 50,000 times. In some cases, photos were received from negatives at a magnification of 2 - 6 times. At each age, 60 myelin fibers with different diameters were used to obtain a scatter plot. The data obtained were subjected to morphometric processing, including the calculation of arithmetic mean values and their errors. The significance of differences was estimated by the method of confidence intervals [20,21].

Results and Discussion

On electron diffraction patterns of the proximal part of the musculocutaneous nerve of the 6-month-old fetus, nerve fibers are visualized at different stages of myelination. Nerve fibers are divided into two groups. Some of them are detected as an accumulation of nerve fibers with a small diameter and a thin myelin sheath, while others with a large diameter and a thick myelin sheath. Myelin nerve fibers are usually round or oval. Of these fibers, the first (small diameter) is usually oval, and the second is rounded. The diameter of myelin nerve fibers is 0.7 - 7.5 microns (an average of 3.5 + 0.02 microns). The thickness of the myelin sheath varies between 0.15 - 0.4 microns (an average of 0.23 + 0.01 microns). The thickness of the axon is 0.4 - 5.2 microns (average 2.9 + 0.04 microns). In the distal part of the nerve, that is, in the lateral antebrachial cutaneous nerve, the myelin fibers are usually small in diameter and have a thin myelin sheath. In those Schwann cells in which the quantity of myelin fibers is less, the distance between the neurolemma and the fiber is greater. In large groups of non-myelinated nerve fibers (usually 15 - 20, occasionally up to 40), this distance is also greater. The cross-sectional size in such non-myelinated nerve fibers varies in the range of 0.13 - 2.19 microns. As the quantity of nerve fibers in the groups increases, the axon diameter decreases. On the contrary, in small groups consisting of non-myelinated nerve fibers, in an amount of 3 - 4, the diameter of the axon is larger. In the early stages of myelination, when the myelin sheath consists of 2 - 3 lipoprotein plates, the axon has a small diameter (0.7 - 2.0 microns). Typically, nerve fibers with a thick myelin sheath have an axial cylinder (axon) of large diameter. But in some cases the opposite picture is noted. For example, in one case, the diameter of the axial cylinder of the myelin-free fiber was equal to the diameter of the nerve fiber having a thick myelin sheath. In another case, two fibers with different diameters (the first 5.0 μm and the second 2.5 μm) had a myelin sheath with the same thickness. In the first nerve fiber, the diameter of the axial cylinder was 4.6 μm, in the second - 2.1 μm. In general, in both parts of the musculocutaneous nerve of the six-month-old fetus, there was a straightforward relationship between the thickness of the myelin sheath and the diameter of the axial cylinder (Figure 1).

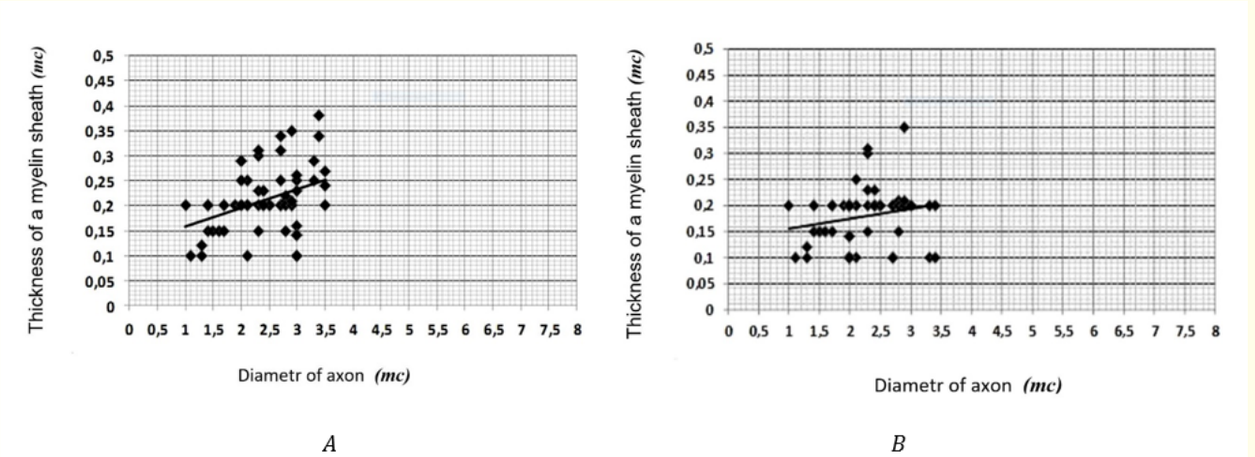

Figure 1: *A graph of the ratio of the thickness of the myelin sheaths to the diameter of the axon in the proximal (A) and distal (B) parts of the muscular-cutaneous nerve of 6-month-old human fetuses.*

The inconsistency of the pattern in a straightforward relationship between the thickness of the myelin sheath and the diameter of the axial cylinder is more characteristic of fibers that are in the early stages of the myelination process. This can be explained by the preservation of the cytoplasmic layers between the lipoprotein plates (despite their insignificant quantity) of the myelin sheath (Figure 2a). Of the two nerve fibers of the same thickness of the myelin sheath (1.15 μm), in the first the quantity of lipoprotein plates 3, in the second - 8. At the same time, the diameter of the axial cylinder was 1.5 μm in the first nerve fiber, and in the second - 1.0 μm. In these cases, the space of cytoplasmic structures is revealed between the myelin sheath and the axial cylinder (Figure 2a and 2б).

Among the more differentiated nerve fibers, there are fibers with a small caliber and a thin myelin sheath (Figure 2B). This attributed to the difference in the functions of nerve fibers in the composition of the musculocutaneous nerve, since the proximal part of this nerve contains fibers designed to innervate the muscles of the anterior shoulder group and the skin of the forearm. In subsequent periods of prenatal ontogenesis - in 7-9 month old fetuses, fibers with a thin myelin sheath are more in the distal part of the nerve. This is due to the sensitive and sympathetic use of these fibers. In addition to sensitive fibers, this part of the nerve contains sympathetic fibers for smooth muscles and glands of the skin of the lateral forearm.

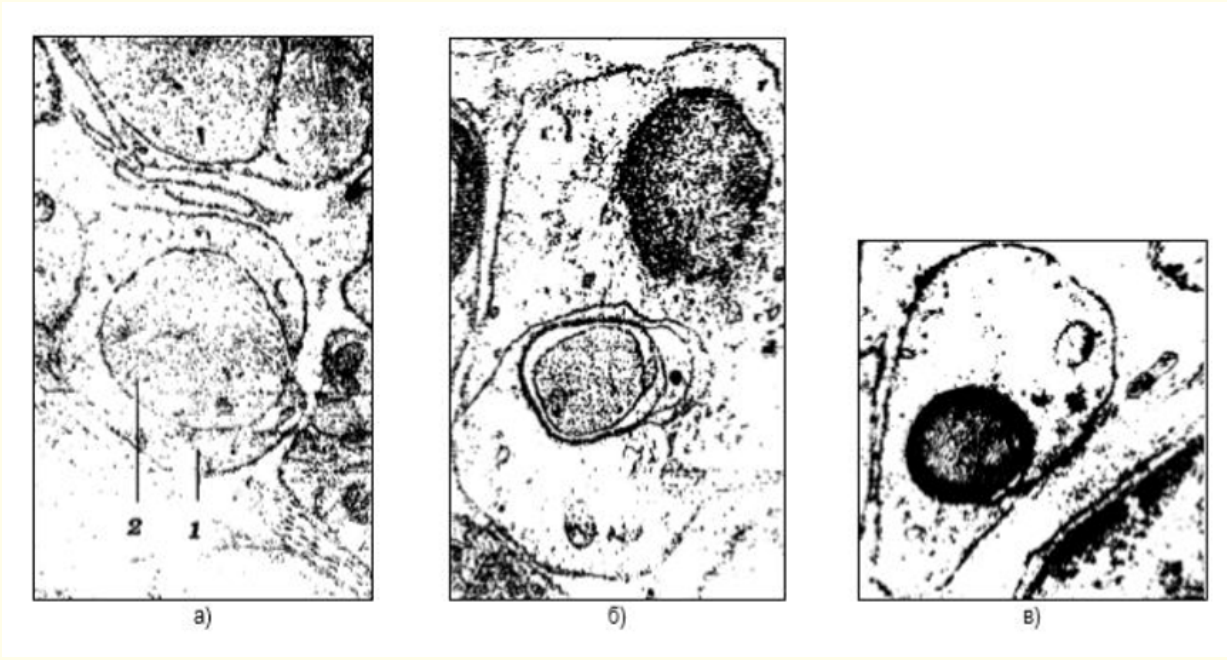

Figure 2: *The process of myelination of the muscular-cutaneous nerve: а - The proximal part of the musculocutaneous nerve of the 6-month-old fetus; the center of the image is occupied by an axial cylinder immersed in a Schwann cell; 1 - Schwan cell; 2 - axial cylinder. б - The distal part of the muscular cutaneous nerve of the 6-month-old fetus. Round-shaped nerve fibers have a myelin sheath consisting of three lipoprotein plates; в - The proximal part of the musculocutaneous nerve of the 6-month-old fetus. Inc: 8,000.*

In a newborn, single fibers with a large caliber of 9.0 - 9.2 μm were noted in the proximal part of the musculocutaneous nerve. Such groups usually consist of 2 - 7 myelin-free fibers. The non-myelin fibers of large groups of the previous stages of the prenatal period turned into myelin nerve fibers of small caliber. In a 9-month-old fetus, a well-formed connective tissue membrane surrounds nerve fibers. The distal part of the nerve usually contains small caliber fibers with a thin myelin sheath. The non-myelin fibers in the distal part of the

nerve are in large groups, which contain up to 40 fibers. The thickness of the myelin sheath of the fibers of the musculocutaneous nerve in a 9-month-old fetus reaches 0.5 - 1.0 microns (an average of 0.34 ± 0.001). Usually consists of 20 - 30 (26 ± 0.1), occasionally more than 50 (72 - 80) lipoprotein plates. If we pay attention to the ratio of the thickness of the myelin sheath to the diameter of the axial cylinder in this period, then a straightforward relationship between them is also noted (Figure 3).

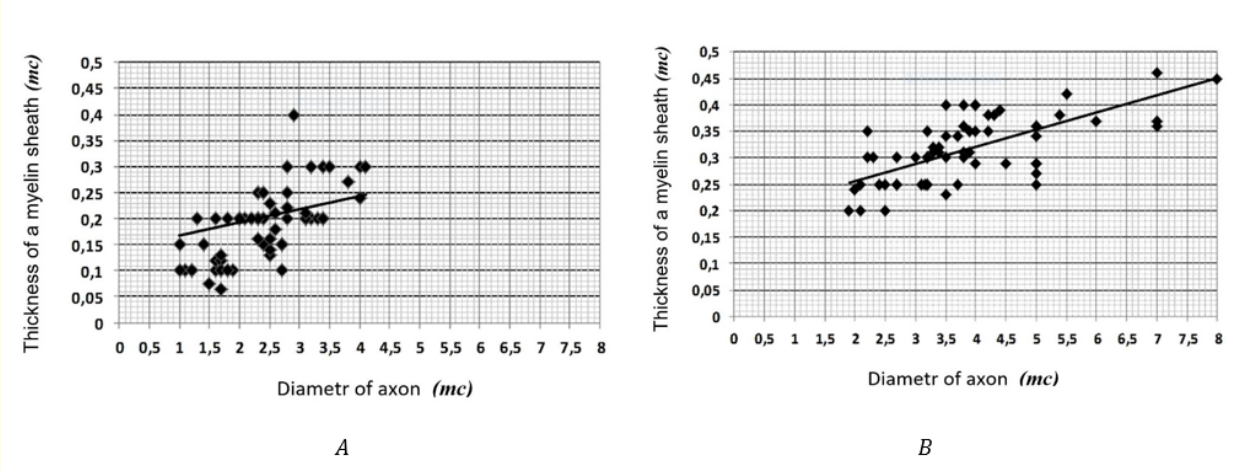

Figure 3: *A graph of the ratio of the thickness of the myelin sheaths to the diameter of the axon in the distal (A) and proximal (B) parts of the muscular-cutaneous nerve of 9-month-old human fetuses.*

Conclusion

However, in some cases, discrepancies from the general pattern are noted. In fibers with different diameters (one - 5.5 μm, the second - 3.0 μm), the myelin sheath with the same thickness (0.4 μm) dominates. The principles of myelin fiber device are the same for all stages of prenatal ontogenesis. However, the 9-month-old fetus has an increase in the total diameter of the myelin fiber due to the thickening of the myelin sheath and the diameter of the axial cylinder. In fruits, the sizes of the structural elements of the myelin sheath of the fibers are often the same for their different diameters. In this regard, our opinions are consistent with existing data from various authors. There is a rectilinear correlation between the thickness of the myelin sheath and the diameter of the axial cylinder. In some cases, discrepancies from the general pattern are noted. Fibers with a thin myelin sheath have an axon with a large diameter or vice versa. This feature is characteristic of fibers at earlier stages of the myelination process. This is due to the preservation of cytoplasmic structures between the layers of lipoprotein plates.

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