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The Windows of the Internal Elastic Lamella of the Cerebral Arteries

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With 5 Figures in the Text

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Material and methods

The large arteries at the base of the brain were taken from 90 necropsies, ten from each age decade over a lifespan of 90 years. In each case the arteries were selected arbitrarily among such showing no macroscopic atheromatous changes. All the material was carefully dissected out, and roughly 1 cm long segments were excised from the following arteries: a) the right and left anterior cerebral arteries at the level of the anterior communicating artery; b) the internal carotid distal to the posterior communicating artery; c) the most proximal portion of the right and left middle cerebral arteries; d) the left posterior communicating artery; e) the anterior portion of the basilar artery; f) the distal portion of the right

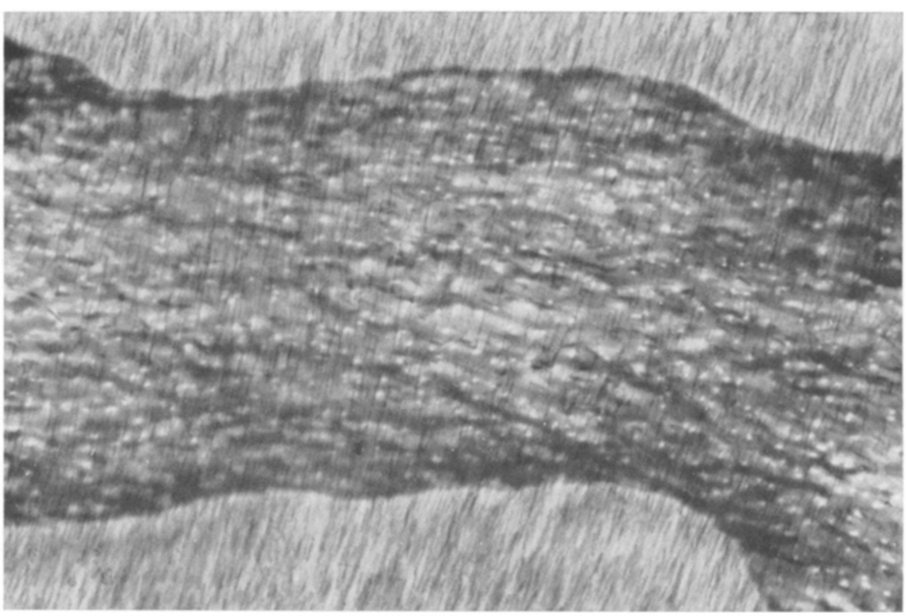

Fig. 1. Tangential section through the wall of a cerebral artery demonstrating the windows of the internal elastic lamella. Smooth muscle cells belonging to the media are seen in the background. (Aldehyde-fuchsin and van Gieson, × 125)

vertebral artery. Each segment was then cut lengthwise at two places so that a rectangular strip roughly 0.3 cm long and 1 cm broad was obtained. This strip was placed on a piece of cardboard and flattened out gently, until it slightly adhered to the base. When the cardboard was gently immersed in Bouin's solution the strip remained in position and could be fixed and dehydrated unfolded. It was then embedded in melted paraffin, together with the cardboard which was not removed until a few hours later. The specimens were sectioned serially in a plane as parallel as possible to the surface of the flat strip. The sections were stained with aldehyde-fuchsin (Gomori 1950) and van Gieson. Even at a fairly low magnification the windows were clearly visible as in Fig. 1. The magnification otherwise used for the investigation was × 1950. The measurements consisted in determining the maximum diameter of the windows in a area of 0.001 mm², selected arbitrarily from each specimen. For this purpose a Zeiss' ocular screw micrometer was employed. Within the same area the portion of the surface of the lamella occupied by windows was determined by means of planimetry. The determination of the number of windows per mm² was facilitated by inserting a circle in the focal plane of one of the eye-pieces of the microscope. The windows were counted within an area of 0.01 mm², selected at random. In the preliminary experiments, a large number of fixatives and elastin stains were investigated with regard to their effect on the size of the windows. No great differences were found but the technique described above proved best.

The thickness of the internal elastic lamella at different ages and in different arterial groups was also investigated in the arteries mentioned above. But these measurements were performed on arterial segments adjacent to those mentioned above. These segments were sectioned in a plane forming right angles with the longitudinal axis of the artery. The sections upon which the thickness of the lamella was measured were taken at random. Only the thinnest part of the lamella was determined. When the elastic lamella was split up into two or more lamellae, the tissue between the lamellae was excluded.

A large material of stained sections from human coronary arteries, human meningeal arteries and the cerebral arteries of horses, cows, sheep, pigs, dogs, and rabbits that had been collected in connection with a previous investigation was used for comparison.

Results

As is shown in Fig. 2, windows with a comparatively small maximum diameter were generally found in the new-borns. The arteries with a great calibre, i.e. the internal carotid and basilar arteries, were regularly found to have smaller windows

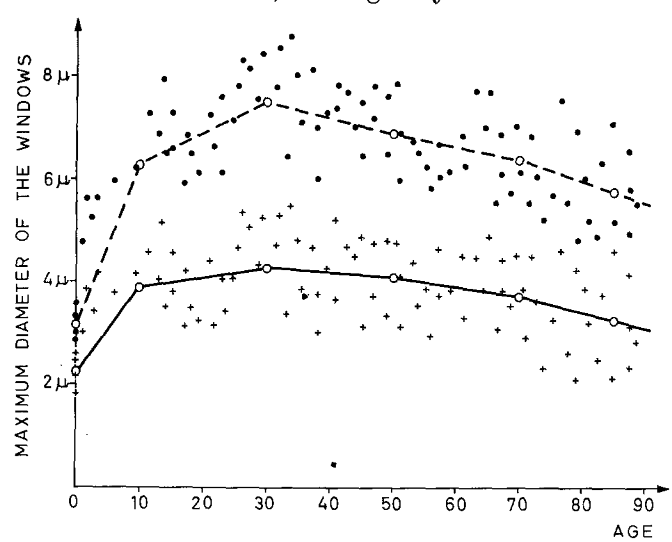

Fig. 2. Diagram to show the maximum diameter of the windows at different ages in the internal carotid (indicated by +) and the anterior cerebral artery (indicated by •)

than the arteries with a small calibre (the anterior cerebral, middle cerebral, posterior communicating arteries, and, when accidentally observed, the small branches of the arteries mentioned).

In new-borns and children the windows were more or less round in shape, whereas in adult individuals they were rather more elongated. The maximum length of the window was as a rule found to be in the longitudinal axis of the artery. The windows of the arteries with the greatest calibre were generally more spool-shaped than those of arteries with a smaller calibre, where the line of demarcation was somewhat more angular and irregular. The windows were not evenly distributed over the surface, but appeared in groups of two to five. Not infrequently "twin"-windows were observed, i.e. two windows separated from each other by a thin stand of elastic fibres.

The number of windows per sq.mm of the elastic lamella was comparatively high in the neonates. The lowest values were observed in the highest age groups.

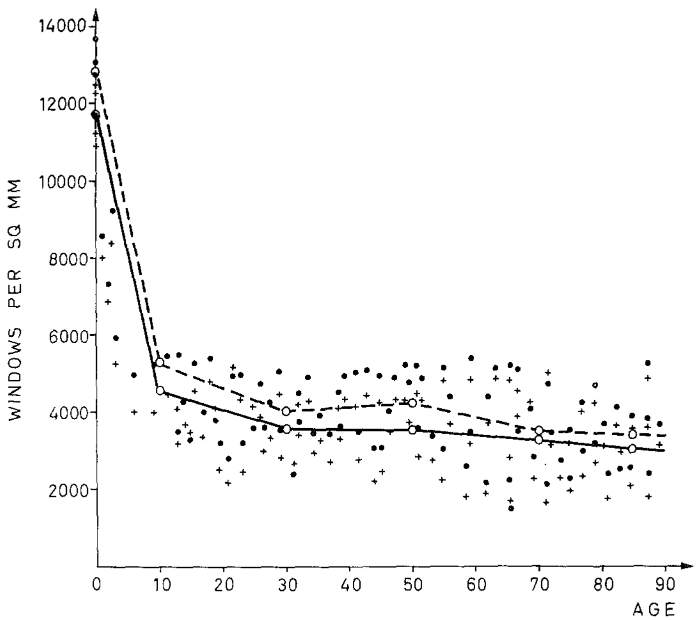

Fig. 3. Diagram showing the number of windows per mm² at different ages in the internal carotid (+) and the anterior cerebral artery (•)

No important difference was observed between the arteries but in general a few more windows per sq.mm were observed in arteries with a small calibre than in those with a greater calibre (cf. Fig. 3).

The part of the lamella occupied by windows was markedly greater in arteries with a fine calibre than in such with a larger calibre (cf. Fig. 4). A decrease in the part of the lamella occupied by windows was seen with increasing age.

In the elastic lamella under atheroma exceptionally small and few windows were commonly observed. Moreover, the windows were slightly smaller and less frequent in arteries showing macroscopic atheromatous changes than in the non-atheromatous arteries, but the difference was not statistically significant.

The windows in the split-up lamellae of the physiological intima cushions seemed to be as large and as frequent as in other parts of the arterial wall.

The internal elastic lamella showed an increase in thickness with increasing age (cf. Fig. 5). The lamella was also thicker in the more proximal arteries than in the distal ones. The thickness of the elastic lamella in the internal carotid was largely the same as that of the lamella in the basilar artery in the individual in question and the thickness of the lamella in the middle cerebral artery of the individual showed similar values to those given in Fig. 5 for the anterior cerebral artery. In the highest age groups the lamella was often split up into two or more lamellae.

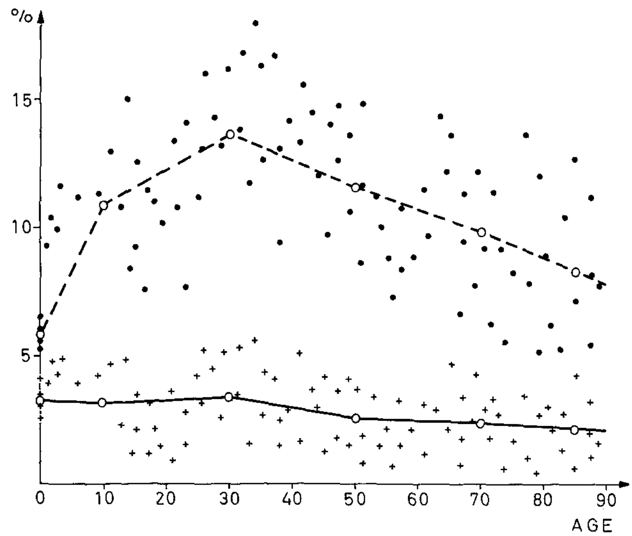

Fig. 4. Percentual area of the elastic lamella occupied by the windows at different ages. • Anterior cerebral artery; + internal carotid artery

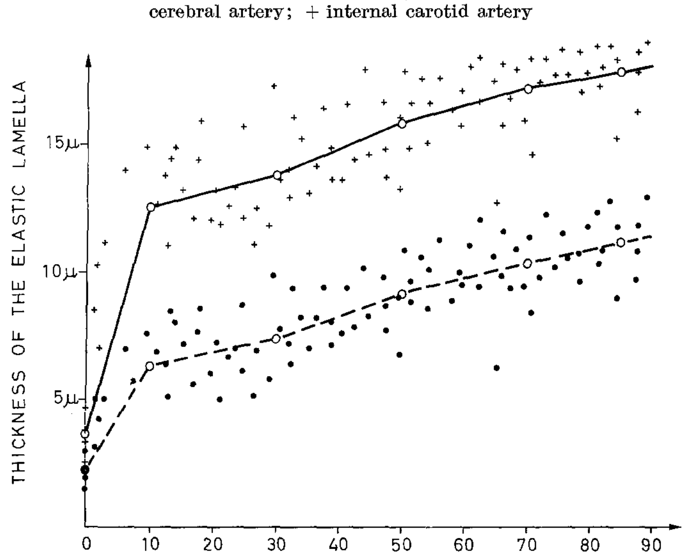

Fig. 5. Thickness of the internal elastic lamella at different ages in the internal carotid (+) and the anterior cerebral artery (•)

The windows observed in the elastic laminae of the coronary arteries of man were in general larger and more frequent than those of the cerebral arteries. This was also the case with the windows of the meningeal arteries in man. The values for the maximum diameter of the windows ranged between 6 and 14 μ in the coronary arteries and between 4.5 and 9 μ in the meningeal arteries.

Of the mammals studied for comparison sheep, pigs, dogs and rabbits were found to possess windows. In all four species the size of these was comparatively large, the maximum diameter ranging between 4 μ and 10 μ in sheep, 3 μ and 9 μ in pigs, 3 μ and 13 μ in dogs and $^1/_2\,\mu$ and 2 μ in rabbits. No windows were found in horses and cows, which might be connected with the fact that in these animals the internal elastic lamina of the cerebral arteries is very thin.

Discussion

The intracranial arteries are poorly equipped with vasa vasorum except in physiological intima cushions and in the case of atheromatosis especially in the internal carotid and the vertebral arteries. Otherwise the cerebral arterial wall is nourished by diffusion from the lumen. The nourishment to the main layer, the muscular media, has to go through the internal elastic lamella. As is shown in this investigation the lamella is exceptionally thick in the adult human cerebral arteries, especially in those with the greatest calibre — the internal carotids, the basilar and vertebral arteries. These three arterial groups were found to have smaller windows than the others. Further there was a decrease in the size and total area of the windows with increasing age. The small windows in the adult internal carotid, basilar and vertebral arteries may thus be assumed to constitute narrow gateways facilitating the important passage of nourishment to the media, especially since these large arteries need a greater supply of nourishment to their media than smaller ones. In cases where the windows are too small to cope with the maximum physiological demands, or where the passage is partly blocked by pathological processes, fibrosis or atheromatous degeneration of the media may occur. The large cerebral arteries with the smallest windows and the thickest lamellae are in fact known to constitute preferred sites for atheromatosis. The lamellae of other arteries are thinner and have comparatively larger windows. Thus problems concerning nutrition probably do not occur in these. Exceptions are the coronary arteries, which normally have two or three elastic laminae in their walls, and the large elastic arteries, which have still more concentric lamellae. Though the windows of the lamellae in these two arterial groups are larger, it is possible that they do not suffice in the case of lamella multiplications, for these groups are known to be predilection sites for arteriosclerosis of various kinds.

The function of the windows of the elastic lamella of the cerebral arteries has previously been discussed by BENNINGHOFF (1927), who suggested that they served as insertion points for the tendons of some smooth muscle cells. In connection with the present and earlier investigations I have examined thousands of windows but I have never seen an insertion of a smooth-muscle-cell tendon into a window. I have also found that the elastic lamella has windows at the sites of media defects (HASSLER 1961). Further, the elastic lamella is extremely loosely attached to the media, which is seen in the case of artifacts, and can be taken advantage of when a separation of the elastic lamella is desired (cf. HASSLER 1961). This would hardly be the case if tendons united the elastic lamella with the media.

Summary

The large cerebral arteries have a relatively thick, compact internal elastic lamella in which small windows occur. The nutrition of the tunica media takes

place by diffusion from the lumen, because the normal cerebral arterial wall generally has no vasa vasorum. The main part of the nutritional transport probably goes through the windows because the compact portions of the elastic lamella are less permeable. The windows may thus constitute narrow gateways facilitating the passage of nourishment to the media. With increasing age the windows get smaller and less frequent at the same time as the elastic lamella increases in thickness. In the largest cerebral arteries these windows were also found to be smaller than in the cerebral arteries with a finer calibre. With increasing age the nutritional supply to the media may therefore be endangered in the largest cerebral arteries, expecially since the media of these arteries needs a greater supply than that of the smaller ones. When the nutritional transport is insufficient media fibrosis and atheromatosis may develop. These lesions are actually most common in the largest arteries.

Zusammenfassung

Die großen Hirnarterien haben eine relativ dicke, kompakte Lamina elastica interna, in der kleine Fenster vorhanden sind. Die Ernährung der Tunica media geschieht durch Diffusion vom Lumen aus, da die normalen Hirnarterien gewöhnlich keine Vasa vasorum besitzen. Der größte Teil des Stofftransportes geht wahrscheinlich durch die Fenster, da die kompakten Teile der Lamina weniger durchlässig sind. Die Fenster stellen also einen Zugang dar, der den Transport zur Media erleichtert. Mit zunehmendem Alter werden die Fenster kleiner, ihre Anzahl verringert sich, gleichzeitig wird die Lamina dicker. Die Fenster der großen Hirnarterien sind kleiner als diejenigen der Arterien kleineren Kalibers. Mit zunehmendem Alter kann deshalb der Stofftransport zur Media in den großen Arterien gefährdet sein, besonders da die Media in diesen Arterien eine größere Stoffzufuhr verlangt als die Media in den kleineren Arterien. Bei nicht ausreichendem Stofftransport kann sich Mediafibrose oder Atheromatose entwickeln, Veränderungen, die tatsächlich häufig in den großen Arterien vorkommen.

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