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THE MICROVASCULAR ARCHITECTURE OF THE VESTIBULE AND THE ENDOLYMPHATIC DUCT AND SAC OF THE RAT IN VASCULAR CORROSION CASTS

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Abstract

The blood vessels of the vestibule and the endolymphatic duct and sac (ES) of the rat were reproduced with methacrylate casting medium and observed under a scanning electron microscope.

Dense capillary networks of the macula utriculi and the macula sacculi were observed. The collecting venules from the vestibule emptied into the vein of the vestibular aqueduct (VVAQ). The plexus of the vessels in the ES was triangular in shape and had anastomoses with vessels of the bone and dura and drained into the VVAQ. The posterior meningeal artery (PMA) gave off two branches to the ES. These findings supported the similarity of the vascularization of the vestibule and the ES between the human and the rat.

Key Words: Inner ear, Microvasculature, Rat, Scanning Electron Microscopy, Vestibule, Endolymphatic sac, Vascular cast.

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Introduction

Hallpike and Cairns (1938) first described the decrease of the vessels in the subepithelial layer of the endolymphatic duct and sac (ES) as a cause of the endolymphatic hydrops in Meniere's disease. In addition, Kimura and Schuknecht (1965) succeeded in creating the experimental endolymphatic hydrops in the guinea pig by obliteration of the ES. Thereafter, the ES accompanying vascular channels were studied by many investigators.

The vascular system of the vestibule and the ES has been believed to play an important role for Meniere's disease. Though the blood vasculature of the inner ear has been studied by conventional light microscopy in the human, the guinea pig, the rat and some other animals (Nabeya, 1923; Smith, 1953; Mazzoni, 1979), the detailed architecture of the vessels or their three-dimensional relationship is ambiguous because of the limited depth of the light microscopy. Recently the vascular architecture of the vestibule of the guinea pig has been demonstrated three-dimensionally using a scanning electron microscope (SEM) of the corrosion casts (Nakai, 1985; Harada, 1984).

This paper describes the microvascular architecture of the vestibule and the endolymphatic sac in the rat by corrosion casts/SEM.

Materials and Methods

Twenty adult healthy Wistar rats weighing 200 to 400 g were anesthetized with diethyl-ether. After the ligation of the descending aorta, the animals were perfused through the canulated ascending aorta first with Ringer's solution and then with a methacrylate resin (Mercox; Japan Vilene Hospital Co., Ltd., Tokyo). The temporal bone and the circumambient dura mater were excised and immersed in a warm water bath (60^{o}C) for 2-3h to completely polymerize the resin then corroded in 20 % KOH or NaOH solution (60^{o}C) for 12-18h and decalcified by Plank and Rychlo's method. The specimens were alternately rinsed with running tap water and 10 % neutral soap (60^{o}C) for 12-18 h. Obtained blood vascular casts of the inner ear were freeze-dried, coated with gold and observed with a scanning electron microscope (JSM-U3, Japan Electric Optic Laboratory, Tokyo).

Results

Anterior vestibular artery (AVA) and the common cochlear artery arose at the entrance of the internal auditory canal from the anterior inferior cerebellar artery, usually independent from each other and occasionally making a common trunk. The common cochlear artery divided into the propial cochlear and the vestibulo-cochlear artery (VCA) near the vestibular portion of the cochlear basal coil.

The arterial supply of the vestibule (Fig.1)

AVA, which ran tortuously through the osseous canal of the superior vestibular nerve, gave off two to four branches to the macula utriculi at the antero-lateral portion of the utricle.

The branches of the AVA entered beneath the sensory cells, decreasing their tortuosity (Fig. 2).

The blood supplies of the saccule derived from the AVA and the VCA. The VCA went down to the posterior semicircular canal as well as the AVA. On its way it ramified a tortuous branch which ran along the anterior margin of the saccule. The AVA gave off a branch which took a course along the superior margin of the saccule. These marginal branches gave off numerous and small arteries or arterioles to the capillary plexus of the saccule (Fig. 3).

The arterial supply of the ES

Two branches of the PMA which derived from the occipital artery entered the ES along both sides of the sigmoid sinus (SS).

In some cases, they gave off numerous twigs to the plexus of the ES from the distal portion and in other cases one of them ran laterally to the SS, coursed along the rim of the ES and ramified numerous twigs to the ES (Fig. 4). The vestibular branch of the VCA did not supply the vascular plexus of the ES.

The small vessels, which could not be arteries ran the VVAQ between the vestibule and the ES.

The capillary network and its drainage

Both the saccular and utricular capillary network, corresponding to the sensory epithelia, took semilunar (Fig. 2) and oval (Fig. 3) shapes. The capillary plexus of the ES was triangular in shape and anastomosed with the vessels of the bone and the dura mater surrounding the ES (Fig. 5). The most prominent feature of the vessels in the ES was of the irregular sinusoid type. Three to four collecting venules were identified (Fig. 6). The vein of the supero-lateral semicircular canal (VSLSC) received numerous twigs on the ventral wall of the utricle (Fig. 7).

The saccular vein (SV) which collected venous blood in the dorsal wall of the saccule, received some branches mainly from the utricle (Fig. 8).

The VSLSC and the SV united and drained into the VVAQ at the orifice of the vestibular aqueduct. Three to four collecting venules from the ES also emptied into the VVAQ (Fig. 8).

The VVAQ ran through the vestibular aqueduct along the endolymphatic duct from the vestibule to the sigmoid sinus.

Discussion

Although the vascular anatomy of the inner ear in various animals has been reported in the literature, the vascular architecture of the vestibule and the ES in the rat was not clear in detail.

In the guinea pig, the vascular structure of the vestibule and the ES has been elucidated by the corrosion casting method/SEM but the venous drainage of those areas remains ambiguous.

In the present study the vascular architecture of the vestibule and the ES of the rat was investigated by the corrosion casting method / SEM. In the rat, the vessels surrounding the ES and the capillary network of the vestibule were confirmed to drain into the VVAQ which was one of the main venous drainages of the inner ear. These findings resemble those of the human described by Nabeya (1923), Mazzoni (1979).

On the other hand, some difference between the human and the rat were found, that is, the VVAQ coursed in a bony canal adjacent to the vestibular aqueduct in the human (Ogura and Clemis, 1971), while it ran through the vestibular aqueduct in the rat.

The ES was surrounded by the dense capillary network in the rat and the guinea pig as well as in the human. Many authors stated that the arterial supplies to the ES came from the branches of the PMA and the VCA in the human (Nabeya, 1923; Bast and Anson, 1949), in the guinea pig (Nabeya, 1923; Rask-Andersen, 1979) and also in the rat (Nabeya, 1923). In the rat, it was not proven that the branches of the VCA supplied the capillary network of the ES though they existed very close to the ES.

In considering the presence of the many morphological similarities in the microvasculature of the vestibule and the ES between the human and the rat, the rat might be a more useful model than the guinea pig to study the anatomy and physiology of the human ES.

Our findings in this study may explain the variety of the development of the experimental hydrops among animal species reported in the literature.

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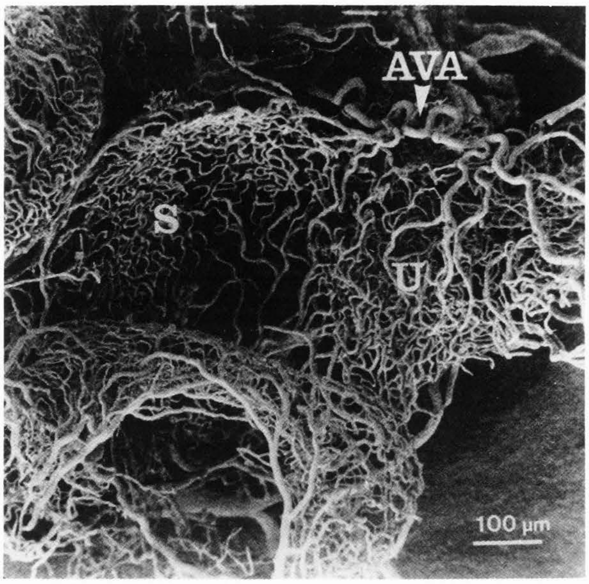

Fig. 1. The capillary network of the utricle (U) and the saccule (S). The anterior vestibular artery (AVA) gave off branches to the saccule and the utricle.

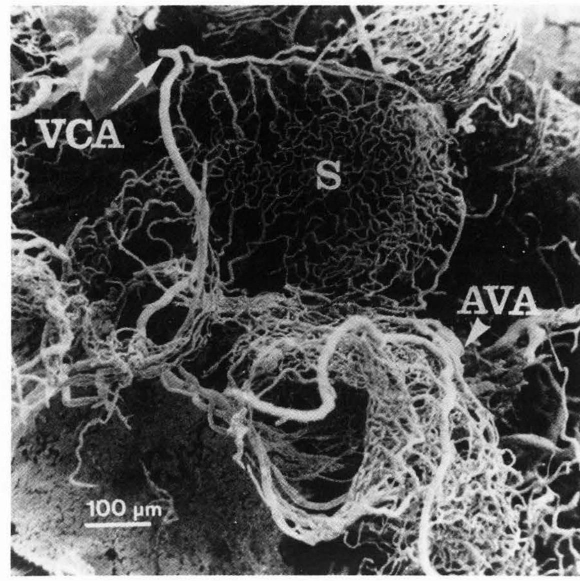

Fig. 3. The arterial supply of the saccule (S). The branches of the vestibulo-cochlear artery (VCA) and anterior vestibular artery (AVA) were observed.

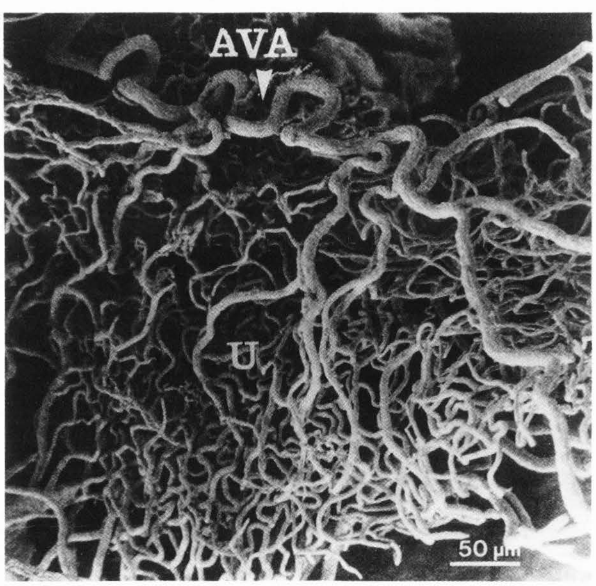

Fig. 2. The arterial supply of the capillary network of the utricle (U). The anterior vestibular artery (AVA) gave off a branch to the saccule before it ramified some branches to the utricle.

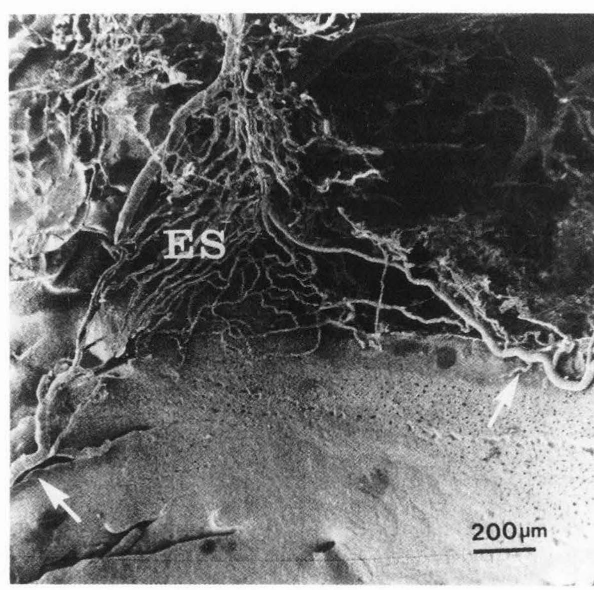

Fig. 4. Arterial supply of the ES. Two branches (arrow) of the posterior meningeal artery (PMA) ran along both sides of the sigmoid sinus for the blood supply of the endolymphatic sac (ES).

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Discussion with Reviewers

Y. Nakai: Is it possible to identify arteries, veins or capillaries by vascular corrosion casts?

Authors: From the imprint of the endothelial cell, it is believed, there could be some discrimination among arteries, veins and capillaries but we couldn't identify it.

Y. Nakai: Did you find any vascular structure with some features in the dark cell area of the vestibule?

Authors: The vascular plexus in that area was

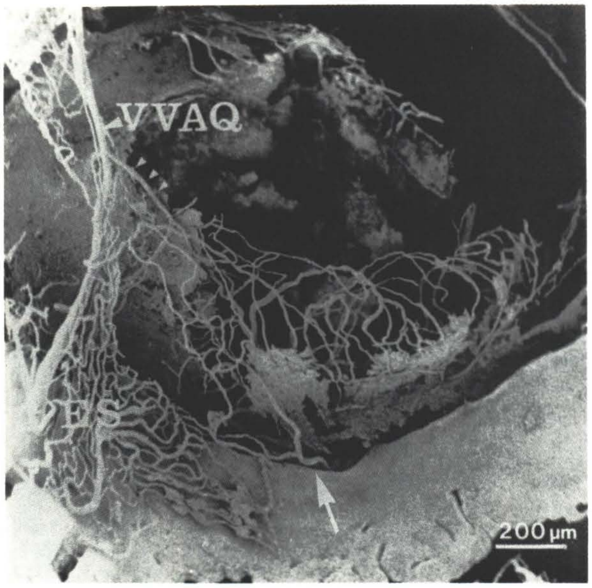

Fig. 5. The capillary network of the endolymphatic sac (ES) has anastomosed with the vessels of the bone and the thick dura surrounding the ES. The branch (arrow) of the posterior meningeal artery (PMA) was supplied to the ES. The branch of the vestibulo-cochlear artery (VCA) ran close to the ES.

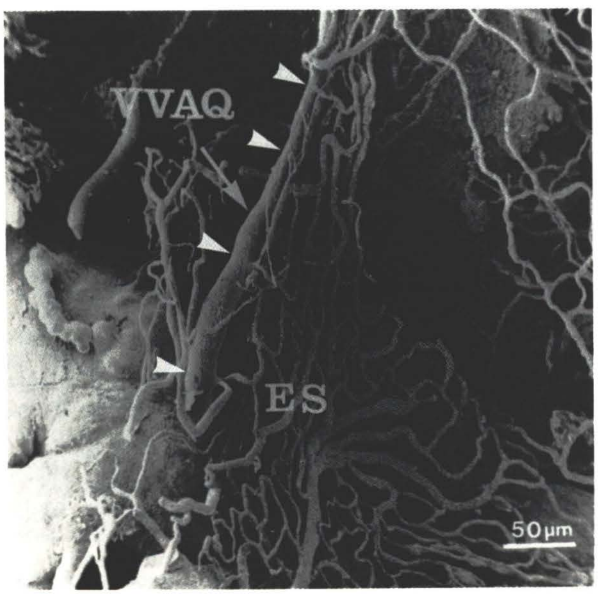

Fig. 6. The capillary network of the endolymphatic sac (ES). The irregular sinusoid capillary is shown. Four collecting venules (arrows) drain into the vein of the vestibular aqueduct (VVAQ).

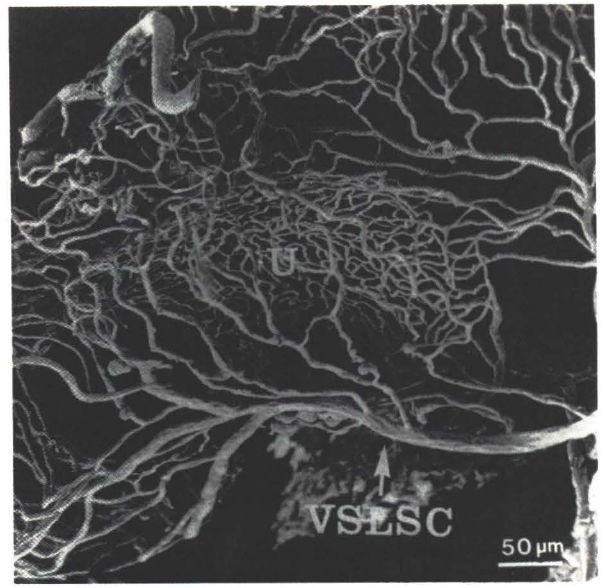

Fig. 7. Venous drainage of the utricle (U). VSLSC: vein of the supero-lateral semicircular canal.

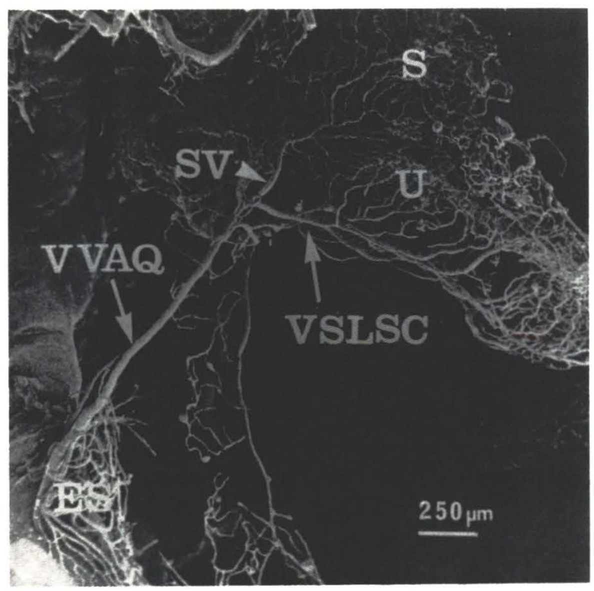

Fig. 8. Drainage system of the vestibule and the endolymphatic sac (ES). The vein of the vestibular aqueduct (VVAQ) drains the vestibule and the ES. SV: the saccular vein; VSLSC: vein of the supero-lateral semicircular canal; U: urticle; S: saccule; VVAQ: vein of the vestibular aqueduct.

sparser compared with the capillaries network of the sensory cells and the endolymphatic sac.

Y. Nakai: The labyrinth artery is absent in many guinea pigs. How about rats?
Authors: The labyrinth artery was absent in many rats, too.

Y. Nakai: In guinea pig the main trunk and arteriolae of the vestibular artery exhibit complicated coiling. But in rats, the coiling is simple. What does the difference imply from the functional and morphological points of view?
Authors: There will be no functional difference between the complicated coiling and the simple

coiling. Both of them are useful to regulate the blood flow to the vestibule. From the morphological points of view there may be species difference.

Y. Nakai: Is there anastomosis of the blood vessel between the saccule and the utricle?
Authors: There was anastomosis of the blood vessels between the saccule and the utricle. Some branches of the utricular vein drained into the saccular vein.

Y. Nakai: In guinea pigs, the capillary network is dense also in the endolymphatic sac. How about in rats?
Authors: In rats, the capillary network was sparse in the endolymphatic duct.

H. Rask-Andersen: According to my experience there are astonishingly few arteries and arterioles generally observed surrounding the endolymphatic sac. What is your opinion in this regard?
Authors: According to our observation some branches of the posterior meningeal artery supplied arteries and arterioles to the endolymphatic sac. We think that these are not so few, even if compared with the arterial supplies to the stria vascularis and the subepithelial area of the sensory cells.

H. Rask-Andersen: The main arterial supply of the endolymphatic sac seems to be derived from branches of the external carotid artery. Internal branches via the vestibular aqueduct of the posterior vestibular artery have also been described. Did you find such anastomosis between the two arterial systems?
Authors: Internal branches via the vestibular artery coursed close to the vestibular aqueduct but we could not identify the anastomoses with the branches of the external carotid artery.

R.S. Kimura: Is there any evidence of fenestrated capillaries or lymphatics in the endolymphatic sac of the rat?
Authors: We have not examined it as yet.