Section of Ophthalmology

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The Retro-orbital Tissues as a Site of Outflow of Cerebrospinal Fluid

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FOLLOWING the extensive researches of Weed (1914) it has been widely accepted that resorption of cerebrospinal fluid takes place mainly into the venous system. The lymphatic connexions of the subarachnoid space, other than those via the arachnoid sheaths of the olfactory nerves and the nasal mucosa, have received scant attention. The relatively few investigations to which they have been subject offer difficulties of interpretation because they were often carried out on the dead animal, (Schwalbe, 1869, 1870), and frequently, too, indicator material was introduced into the subarachnoid space under pressures greatly in excess of the normal. Moreover, when particulate material was employed no indication has been given of particle size. Following a review of the literature, the authors devised a method whereby indian ink, of particle size ranging between 0·5 and 1·5 μ, could be introduced into the cranial subarachnoid space of the living rabbit under conditions which precluded any rise of intracranial tension above the normal (Brierley and Field, 1948). Through a small burr hole in the parieto-occipital region cerebrospinal fluid was withdrawn from the cisterna magna or transverse fissure, and a syringe of sterile indian ink connected to the needle, the ink meniscus being about 120 mm. above the animal's skull. In this way ink was allowed to run in to replace the fluid withdrawn. When no more would run the needle was smartly withdrawn and the burrhole sealed with bone wax. The volume of ink introduced in this way was usually rather less than that of the fluid initially removed. The procedure was sometimes repeated on successive days when it was found that progressively smaller introductions could be achieved, but there was no rise in intracranial pressure.

Examination of animals at intervals of four to ninety-six hours after operation revealed an extensive communication between the spinal subarachnoid space and the prevertebral lymph nodes (Brierley and Field, 1948; Field and Brierley, 1948) and also between the cranial subarachnoid space and the lymphatic plexus of the nasal mucosa (Field, Brierley and Yoffey, 1949). The subarachnoid sleeve of the optic nerve, as might be expected, was well filled with ink. However, on removing the eyeball the retro-orbital fat was also found to be ink-stained. Further investigation of this outflow was facilitated by the use of albino animals in which the absence of pigment simplified the recognition of ink. This latter was found to accumulate in the fatty tissue around the optic nerve immediately behind the posterior pole of the eyeball and to spread laterally for a few millimetres in the episcleral plane. Viewed from the inside of the eye this gave the appearance of radiating black lines passing out from the optic nerve head. Ink permeated the retractor bulbi muscle and the extrinsic ocular muscles, particularly at their scleral attachments. Histological examination showed ink particles passing through the dura-arachnoid sheath of the optic nerve close behind the sclera and coming to lie in the adjacent fatty tissue (fig. 1). Whilst many particles were contained within macrophages, others were free and appeared to have passed directly through the dura-arachnoid. In meridional

section this migration of ink could be seen to extend some little way back along the optic nerve. In the retro-orbital fat there appeared more or less well-defined "fountains" of ink particles, though no endothelial-lined channels could be made out (fig. 2). Further spread in the episcleral plane is shown in fig. 3 where particles of ink are seen immediately outside the sclera several millimetres from the optic

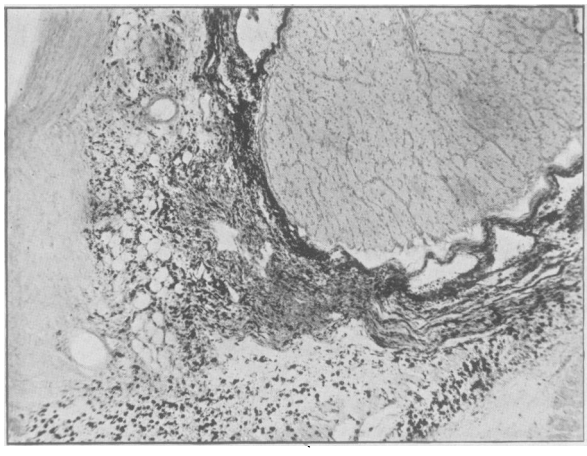

FIG. 1.

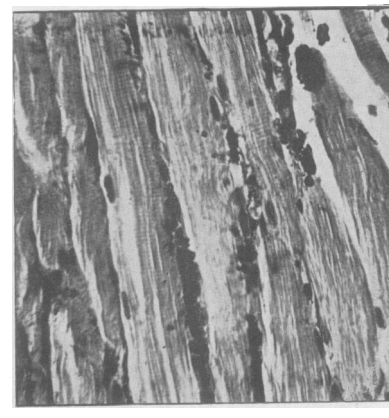

FIG. 4.

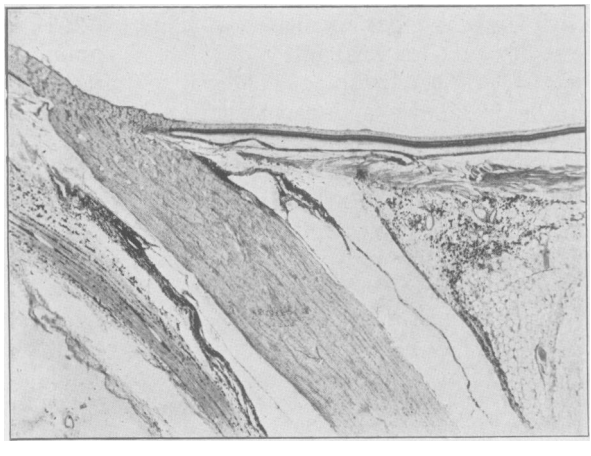

FIG. 2.

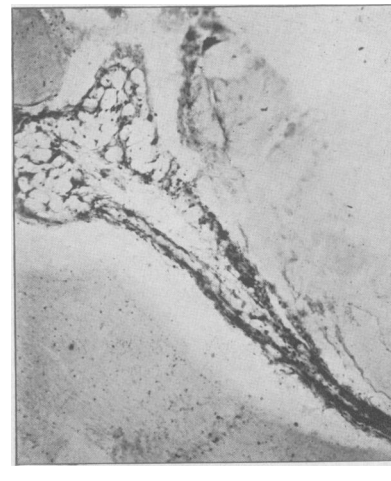

FIG. 5.

FIG. 1.—Transverse section through the optic nerve about 1 mm. behind the posterior pole of the eye. Above and to the right is the nerve, and particles of ink are seen to have passed through its dura-arachnoid sheath into the surrounding retro-orbital fat. Celloidin section. × 35.

FIG. 2.—Meridional section of optic nerve head. On the right indian ink is seen to have escaped into the neighbouring fat and is making its way laterally in the episcleral plane. On the left ink is seen to have permeated the retractor bulbi muscle. Ink escape takes place for several millimetres behind the nerve head. Celloidin section. × 15.

FIG. 4.—Particles of indian ink are seen streaming between muscle fibres of the retractor bulbi. Many of the particles are extracellular. Celloidin section. × 225.

FIG. 5.—Strand of indian ink passing away from the optic nerve sheath through the orbital fat. The optic nerve is in the upper left corner of the figure. Celloidin section. × 75.

nerve head. Microscopic examination of the retractor bulbi muscle showed particles of ink in columns between muscle fibres. Many particles were intracellular but some were still free (fig. 4).

To elucidate the further path which such retro-orbital ink might take, another series of experiments was undertaken. By means of a curved needle introduced through the superior conjunctival fornix, 0·5 ml. of ink was deposited close to the posterior pole of the eye. At intervals of twelve to twenty-four hours after operation the animals were sacrificed and examined. It was found that after some twenty-four hours the superior pole of the uppermost deep cervical lymph node had become ink-stained.

Semiserial celloidin sections of the whole orbital content failed to reveal true endothelial-lined lymphatic vessels, but showed that spread of ink particles took place along more or less definite lines through the fat. Columns of ink could be traced out through the orbital fissure into the deep pterygoid region where true lymphatics were present. Through these, ink was conveyed to the uppermost deep cervical gland. The appearance of a strand of ink in the orbital fatty tissue is shown in fig. 5. The passage of ink (and presumably also of fluid) from the retro-orbital tissue to the cervical lymphatic system is a slow process. It may be that the normal movements of the eyeball facilitate flow in much the same way as muscular contraction increases lymph flow in other parts of the body.

In none of our preparations was ink found within the retina or choroid. Likewise, under the given conditions, ink was never found to pass into the ocular fluids. Wegefarth (1914), using the crystalloid Prussian blue mixture of Weed (1914), came to the conclusion that the "respective fluids of the brain and eye intermingle and mix" in the tissues of the optic nerve. When pressure in the eye was reduced by opening the aqueous, Prussian blue injected into the subarachnoid space was found to pass "beneath the sclera as far forward as the limbus". Histological investigation showed that the indicator was located between the choroid and sclera as far as the ciliary body. It is interesting to note, however, that in the contralateral intact eye the injection material "had gone forward only as far as the posterior pole of the bulb, where there was a very light blue haze around the orbital end of the nerve".

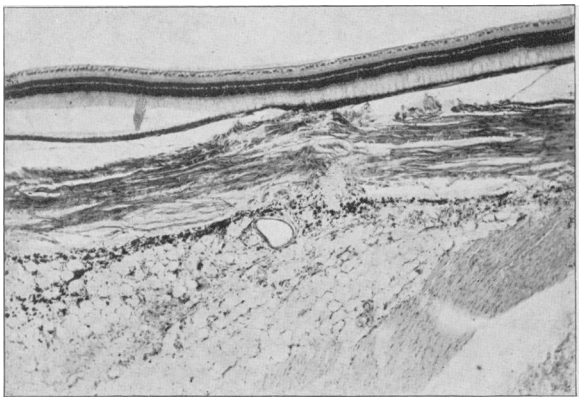

FIG. 3.

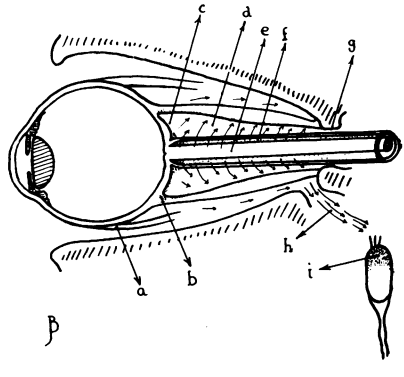

FIG. 6.

FIG. 3.—Ink particles are seen in the episcleral tissue some little distance lateral to the optic nerve head. Celloidin section. × 48.

FIG. 6.—Diagram to illustrate the path taken by indian ink following its escape from the sheath of the optic nerve. a, extrinsic ocular muscle; b, retractor bulbi muscle; c, ink in the fat behind the posterior pole of the eye; d, ink passing out from the optic nerve sheath into the fat some little distance behind the nerve head; e, optic nerve; f, ink-filled extension of the subarachnoid space around the optic nerve; g, optic foramen; h, ink streaming out of orbital fissure; i, uppermost deep cervical lymph node showing ink in its superior pole.

Wustmann (1933) using thorotrast in the surviving dog found by X-ray examination that it could pass from the subarachnoid space to the back of the eyeball, and out towards the medial side of the eye. He describes the thorium as located "... epichoroideal in den Lymphräumen des Augenapfels". Further passage took place through perivascular spaces and "Lymphspalten". It is not clear from Wustmann's account whether strict precautions to prevent a rise in intracranial pressure were observed.

Schwalbe (1870) claimed to have demonstrated a connexion between the subarachnoid space and the perichoroidal space, though his experiments, carried out as they were on dead animals and at injection pressures of 60–80 mm.Hg, cannot be regarded as physiological. He found that Prussian blue could be induced to travel in the episcleral space as far as the venæ vorticosæ and thence into the perichoroidal space along the sheaths of these vessels. Whilst not denying that crystalloid material in the cerebrospinal fluid may indeed be induced to take the paths described by Schwalbe and Wegefarth, the authors believe that under normal conditions what small amount of fluid does escape into the retro-orbital fatty tissue takes the path indicated in fig. 6, to be absorbed finally into the cervical lymphatic system.

Brief reference may be made here to the work of Birch-Hirschfeld (1930) on the spread of indian ink in the retro-orbital tissues. He worked with living rabbits, monkeys and dogs and found ink to spread in the form of long branching strands apparently similar in appearance to those observed by us. In order to increase lymph flow in the orbit he treated some animals with dionin or paraphenylenediamine hydrochloride. Such animals developed exophthalmos because of the increased fluid in the retro-orbital fat, and when this tissue was examined histologically strands of indian ink were found to be confined largely to definite "Spalträume" or tissue spaces. Birch-Hirschfeld thought these spaces were lined by flattened endothelial cells but was not inclined to designate them true lymphatic vessels. The same appearances have been noted in our own material and they suggest that lines of least resistance serving as conduits for tissue fluid may exist between columns of fat cells. The flattened lining cells appear to be merely the nuclei of fat cells which chance to border on the fluid channel.

In conclusion, it may be pointed out that the outflow of cerebrospinal fluid (1) from the arachnoid culs-de-sac around the spinal nerve roots, (2) from the arachnoid sheaths of the olfactory nerves, and (3) from the sheath of the optic nerve present certain features in common. In each case particles of ink make their way through a membrane to emerge in fatty areolar tissue outside: in the epidural fat of the intervertebral foramen, in the stroma of the nasal mucosa and in the retro-orbital fat respectively. In the two former situations true lymphatic channels are close at hand (Field and Brierley, 1948; Field, Brierley and Yoffey, 1949) so that but a small drift in tissue spaces need take place before the particles are collected into lymphatic radicles. In the case of the orbit, however, the fatty tissue surrounding the exit site of the ink is extensive and a slow, prolonged drift must occur before the nearest lymphatic vessels are reached.

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