A CASE OF HYDROCEPHALUS AND MENINGOENCEPHALOCELE IN A RABBIT, CAUSED BY AQUEDUCTAL MALFORMATION

by

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SUMMARY

The hydrocephalic brain of a 3-week-old rabbit with a meningoencephalocele is described. The hydrocephalus is caused by obstruction of cerebrospinal fluid circulation in the aqueduct, which is anomalously formed by several minute tubules surrounded by ectopic ependymal cells. The encephalocele is an atrophied part of the right ventricle forced out of the skull by increased CSF pressure. It is suggested that the aqueductal malformation is caused by an ependymal developmental disturbance.

Although cases of hydrocephalus in laboratory and domestic animals have often been described (Frauchiger & Fankhauser, 1957; Kalter, 1968), little literature exists on hydrocephalus caused by obstruction of cerebrospinal fluid circulation in a malformed aqueduct of Sylvius: only 1 such case has been described (Fankhauser, 1959). In this paper we shall report a similar malformation, accompanied by a meningoencephalocele, in a young rabbit.

MATERIALS AND METHODS

The rabbit belonged to a group of highly inbred animals with a high mortality rate of unknown cause. The 3-week-old rabbit was perfused with saline under ether anaesthesia and fixed in 10% formalin. After the brain had been removed from the skull, it was impregnated with celloidin, and sectioned transversely at 20 μm. The extracranial part of the brain (meningoencephalocele) was separately embedded and sectioned. The hypophysis and spinal cord were sectioned at 8 μm, after paraffin embedding. Sections were stained with luxol fast blue-cresyl fast violet stain, Nissl stain, Weil's myelin stain, and haematoxylin and eosin.

A 3-week-old rabbit was used as control. Central nervous system nomenclature is according to Winkler & Potter (1911) and Young (1936).
RESULTS

When we examined this 3-week-old rabbit it was somnolent and retarded in size and weight in comparison with its litter-mates. A cone-shaped tumour was situated at the top of the head. The animal did not react to visual or acoustic stimuli, but it did react to painful stimuli. The labyrinthine reflexes were bilaterally present. The rabbit did not rise after it had been laid on its left side, it did after being laid on its right side. Strong extensor thrust of the hind-legs followed after they had been pushed firmly on the floor. Spontaneous walking was not observed.

After the skin had been removed during post-mortem examination, a 15-mm-high, fluid-filled vesicle was visible (Fig. 1). When this structure had been amputated, there was a view into the enlarged cerebral ventricles through a round 14-mm-wide hole in the parietal bones, its centre being situated slightly to one side of the mid-line (Fig. 2). The cranial vault was dome-shaped.

![Fig. 1. Lateral aspect of the skull. The skin has been removed.](image)

Microscopic description

Telencephalon. Both olfactory ventricles were enlarged and the surrounding neural tissue was reduced—basally it consisted of only a thin membrane. Although different cell-layers, the lateral olfactory tract and the fila olfactoria, could be distinguished, they were not as distinct as in the normal animal.

The structures situated between sections 100 and 350 (Fig. 2) are shown diagrammatically in Fig. 3. The very thin right cerebral cortex was extroverted
and continued extracranially forming an encephalocele. The left cerebral hemisphere had a small ventricle communicating with the olfactory ventricle. The cell and fiber structure of the dorsal left cortex gave the impression of a chaotic pattern of gyri and sulci. This malformed area appeared to be compressed by a vesiculous formation comprising the right dorsal cortex, the encephalocele, the choroid plexus, and a membrane fused with the left median cortex and continuing on the right median cortex. The membrane consisted of a single layer of squamous epithelium, with cellular clusters at various places. The encephalocele was formed by a bilaminar squamous epithelium, respectively covered by highly vascularized loose connective tissue (pia mater) filled with leucocytes, fibrous connective tissue (dura mater), derma and thin epidermis with hair follicles. More caudally the right and left cerebral cortex gradually became very thin (Figs 4, 5, 6 and 7). Neural elements were almost completely lacking, and the ependyma was squamous and locally defective. A bilaminar epithelial membrane (Figs 4 and 5) extended from the right dorsal cortex to the hippocampus. A small number of myelinated fibers near the
right hippocampal formation formed a rudiment of the corpus callosum (Fig. 4). The caudate nucleus and putamen were underdeveloped, the right half of the brain being more severely affected than the left one. The internal capsule was extremely hypoplastic. The pyriform cortex, olfactory tubercle, olfactory ganglia, amygdaloid complex and anterior commissure showed no gross malformations (Figs 4 and 5). Both hippocampal formations were underdeveloped and had a vertical position which is normal in foetal stages only (Fig. 5). Only the right fornix could be traced using a stain for myelin
The choroid plexus connecting both hippocampal formations was displaced dorsally and stretched out between the cerebral hemispheres (Fig. 5).

**Diencephalon.** The anterior and lateral thalamic nuclei were underdeveloped and as a result the thalamic width was reduced. The medial, ventral, and reticular thalamic nuclei, the lateral geniculate body and the massa intermedia showed a better development. The left part of the thalamus was smaller than the right (Fig. 5). In the hypothalamic area, the mamillary body, the right fornix, the fasciculus retroflexus, the tractus mammillo-thalamicus could be distinguished. Hypothalamic nuclei could not be identified. The preoptic recess was enlarged and had, especially basally, thin walls. The optic chiasma was displaced ventrally; both optic tracts could be traced on their way to the lateral geniculate bodies (Fig. 5). The ependyma in the slightly enlarged 3rd ventricle was lacking at several places, and pieces of neural tissue protruded through these defects into the ventricle (Fig. 6). Ependyma-lined tubules and diverticules could be observed in the diencephalic tissue near the ventricular surface. The hypophysis showed no abnormalities.
Fig. 5. Section 550. Weil's myelin stain. Line represents 1 mm. * membrane (see text); IC internal capsule; Opt C optic chiasma; CN caudate nucleus; Ch P choroid plexus; HC hippocampus; F fimbria hippocampi; Olf Tr olfactory tract.

Fig. 6. Section 750. Weil's myelin stain. Line represents 1 mm. * membrane (see text); Ep epiphys; H habenula; Opt R radiatio optica; C Ped pendunculus cerebri; CGL corpus geniculatum laterale; V III ventricle III; Ret Ne nucleus reticularis thalami; Med Ne nucleus medialis thalami.
Mesencephalon. The right anterior and posterior colliculi, covered by the right cerebral hemisphere were flattened; the left anterior and posterior colliculi were laterally displaced (Fig. 7). Caudally to the subcommissural organ the aqueduct of Sylvius split to form several minute tubules and a wide cleft; the tubules did not seem to be permeable except the ventral one (Fig. 8). Groups of ectopic ependymal cells were scattered between these structures. The tubules united (section 1285) to form a cavity which continued caudally into the 4th ventricle. A great number of tubules was seen in the posterior colliculi; they came to a dead end caudally. Many mesencephalic structures could be distinguished: commissura posterior, subcommisural organ, substantia grisea centralis, fasciculus longitudinalis posterior, nucleus ruber, substantia nigra, formatio reticularis, lemniscus medialis and lateralis, fasciculus retroflexus, pedunculus cerebri (the left peduncle being smaller than the right one), neri III and IV and the corresponding nuclei, decussatio nervi IV, nucleus interpeduncularis, decussatio brachii conjunctivi.

Metencephalon and myelencephalon. The cerebellar vermis and hemispheres were displaced caudally, whereas a part of the right cerebral hemisphere had
Fig. 8. Drawings of serial sections of the aqueduct of Sylvius. Ectopic ependymal cells are indicated by dots, defective ependyma by stippled lines. Line represents 1 mm.

taken their place (Fig. 7). The lobus petrosus had a normal position. The medial and intermediate cerebellar nuclei were situated caudally in relation to the lateral nucleus, which was lying in the lobus petrosus. In the control brain all cerebellar nuclei were situated in a transverse plane. Brachium pontis, brachium conjunctivum and corpus restiforme were present. The cerebellar cortex was normally developed. The roof of the 4th ventricle (velum medullare anterius) was fused with the ventricular floor at some places,
thus locally transforming the ventricle into 2 longitudinal compartments. Many metencephalic and myelencephalic structures could be distinguished: nuclei of nervous V, tractus spinalis of nervus V, nervus V, nervi VI, VII, VIII, IX, X, XI, XII, and corresponding nuclei, pons, and pontine nuclei, corpus trapezoidum, oliva superior and inferior, tuberculum acusticum, tractus pyramidalis (the left one being smaller than the right one), lemniscus medialis, lemniscus lateralis, fibrae arcuatae, formatio reticularis, nucleus gracilis, nucleus cuneatus, substantia gelatinosa. No malformations of the cervical, thoracic, lumbar or sacral spinal cord were observed.

**DISCUSSION**

In the present case, hydrocephalus is caused by aqueductal obstruction of cerebrospinal fluid circulation. The consequent increased intraventricular pressure has caused atrophy and ventricular dilatation rostrally to the aqueduct of Sylvius. The right cerebral hemisphere has partly been forced out of the skull and has compressed the rostral part of the left cerebral hemisphere. The rudimentary development of the corpus callosum is influenced by the cortical atrophy. Since the corpus callosum develops in a rather late foetal stage the neural cells probably were atrophied before the commissure could have developed by axonal outgrowth. Also the anomalous position of the hippocampal formation might be an influencing factor.

In several parts of the present brain ependymal anomalies can be observed: an ependymal membrane in the right cerebral ventricle, ependyma-lined tubules and diverticles in the diencephalic tissue, aqueductal malformations, fusion of the roof and floor in the 4th ventricle. We think that all these phenomena should be considered as the results of one basic developmental disturbance affecting the foetal ependyma. The aetiology is not clear; it might be infectious, or it might be a genetical consequence of the high degree of inbreeding in our stock.

Human hydrocephalus caused by aqueductal anomalies has been extensively described by Russell (1966), who distinguished 3 types of aqueductal deformity: gliosis, stenosis and forking. Our case belongs to the last category. The lack of ependyma in the cerebral and 3rd ventricles and aqueduct should be considered as a result of the increased intraventricular pressure. The aqueductal obstruction must have been established in a late stage of foetal development, as the aqueduct is so wide in earlier stages that the fluid circulation cannot be impeded by ependymal anomalies.

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