13
Pathophysiology of Communicating Hydrocephalus: Information Provided by the New Imaging Modalities

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INTRODUCTION

This chapter addresses the physiology of CSF with particular emphasis upon the dynamic process of communicating hydrocephalus. Utilizing traditional morphological and physiological techniques of histological and ultrastructural analysis (Price et al., 1976; James et al., 1980; Diggs et al., 1986) correlated with autoradiography (Strecker et al., 1973, 1974), radioactive transfer measurements (James et al., 1970, 1972) and cisternography, we have documented certain associated structural and functional abnormalities in communicating hydrocephalus as well as the compensatory and repair mechanisms. Recently we have employed the modality of magnetic resonance imaging (Partain et al., 1988b,c) and its dynamic capabilities (Price et al., 1987) to further the understanding of CSF physiology as it relates to communicating hydrocephalus (Bradley et al., 1986, 1989; Davson et al., 1987).

Communicating hydrocephalus results in a relative imbalance of production of CSF fluid and its absorption. Absorption is most often compromised by closure of pathways of CSF flow and drainage (Deland et al., 1972). Early in the development of communicating hydrocephalus, the CSF pressure is elevated (Vessal et al., 1974), but as the cerebral ventricles enlarge, the pressure and ventricular entry decrease to the normal range, except for transient episodes of pressure elevation.

The transfer of labelled substances from CSF (Davson et al., 1962) into
the blood is also compromised (Strecker et al., 1977), despite the fact that CSF production continues at a normal rate (James et al., 1973). With the cerebral ventricular enlargement at the expense of the neuropil, a series of morphological changes have been observed which suggest an attempt to respond to the physiology. These phenomena remained underinvestigated, owing to the fact that an appropriate experimental model for this disorder had not been developed. In the early 1970s such a model was developed in our laboratory (James et al., 1974a, 1977).

Chronic communicating hydrocephalus can be induced in Macaca fasicularis monkeys by subarachnoid placement of a room-temperature mixture of Silastic (Dow Corning Chemical Corporation, Midland, MI). Although certain aspects of the technique have been previously reported, these will be summarized. The skin overlying the external occipital protuberance is shaved and aseptically prepared. Using this same midline landmark as a guide, a 17 gauge needle is inserted through a small incision and the needle advanced carefully to avoid the medulla. After appearance of clear CSF, a 19 gauge polyethylene catheter is introduced through the needle into the basal cistern. Free flow of CSF is used to ascertain proper catheter placement. Approximately 1 ml of a mixture of dimethyl polysiloxene, polysiloxene with filler and a catalyst (stannous octoate) is injected into the subarachnoid space. The animal is then left supine with its head in the dependent position for approximately 10 min to facilitate adequate flow cephalad and polymerization of the Silastic (Figure 13.1).

At sacrifice, all animals are anaesthetized with sodium pentothal, heparinized and transcardially perfused with Karnovsky’s fixative (2.5% formaldehyde freshly depolymerized from paraformaldehyde and 1.0% glutaraldehyde in 0.1 M phosphate buffer, pH 7.2). The brains are removed and stored in the same fixative until samples are prepared for examination with transmission (TEM) and scanning electron microscopy (SEM).

The tissue is processed for SEM by modification of the OTOTO method. Samples are rinsed in 0.1 M phosphate buffer, pH 7.2, and post-fixed for 2 h in 1% OsO₄ in the same buffer. Six distilled water washes are followed successively by treatment with 1% TCH (30 min), 1% OsO₄ (2 h), 1% TCH (30 min) and 1% OsO₄ (2 h). Between TCH and OsO₄ treatments and after final incubation with OsO₄, samples are washed six times for 2.5 min each with distilled water and dehydrated through a graded ethanol series, critical-point dried from CO₂ and cemented to aluminium stubs with colloidal silver paste. Samples are then viewed without further coating in a Hitachi S-500 scanning electron microscope at 20 kV.

Specimens for TEM are dissected into blocks (1 × 1 × 0.5 mm) post-fixed in cacodylate-buffered 1% osmium tetroxide, rinsed in buffer, dehydrated in graded ethanol series, critical-point dried from CO₂ and embedded in Epon 812. Semithin (1.5 μm) sections are cut and stained with methylene blue and Azure II. The ultrathin sections are stained with