Evaluation of Photoscanning of the Diffusion of Intrathecal RISA in Infantile and Childhood Hydrocephalus

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The limitations of pneumography for delineation of available extraventricular subarachnoid space have encouraged us to examine the use of radioactive isotopes. The rate of diffusion and distribution of an isotope confined to this space could permit, by external scanning, an estimation of cerebrospinal fluid (CSF) distribution and dynamics. In contrast to pneumography, the procedure would not simultaneously disturb the CSF dynamics, and information so derived might be useful for assessing the severity and progress of hydrocephalus.

The physiological basis rests upon the observations of Sweet and others, namely, that labeled protein is confined to the CSF space and, by diffusion and directional flow, passes over the hemispheres ultimately into the venous system along the major sinususes. The first clinical applications were for demonstration of spinal blocks. Later, Di-Chiro, with others, developed methods for demonstrating CSF fistulas, arachnoid cysts, porencephaly, and hydrocephalus, and introduced the term "isotope cisternography," which has been generally adopted. Currently the technique is being tried in studies of communicating hydrocephalus in adults.

Our investigations were to assess the possible diagnostic usefulness in childhood and infantile hydrocephalus by correlating the isotopic findings with the degree and progression of the hydrocephalus as determined by previous pneumography, ventriculography, and clinical parameters. Some of the children were studied before and following insertion of ventriculoatrial shunts. Our experience so far includes 51 scans in 45 patients. The majority of these patients had hydrocephalus (28 infants and children, 12 adults) but we also included cases of pseudotumor cerebri, CSF rhinorrhea, and adult cerebral atrophy.

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Methods

The instrument for scintillation scanning was the Nuclear Chicago Pho-gamma III which produces a Polaroid print for each scanning interval in about 3 minutes and is thus well suited for use in infancy. Scans may be repeated at frequent intervals without necessitating a single prolonged period of full cooperation. However, most of the infants required some sedation with a Demerol-phenerganthorazine mixture in appropriate doses.

Saturated solution of potassium iodide (2 to 3 drops per day for 5 days) was administered to block thyroid uptake. Fresh, undiluted, high-specific-activity radiiodinated serum albumin (RISA) containing 500 microcuries (μc) per milliliter was injected, by barbotage, into the lumbar CSF. Doses of 2 to 5 μc per kilogram in volume of .05 to 0.5 cc were used. The spine and calvarium were scanned initially at 10 to 30 min intervals and thereafter at 1- to 4-hour intervals in both anteroposterior and lateral projections over 24 to 36 hours. Extra-arachnoid injection, which occurred in three infants, became obvious within the first 30 min.

Results

All the infants and children were evaluated as to etiology and degree of hydrocephalus by ventriculography, pneumoencephalography, and clinical parameters including progress of head growth, measurement of intracranial pressure, psychomotor development, and relative ventriculoatrial shunt dependency.

Normal Control Studies. Two nonhydrocephalic infants were scanned as controls. The first was 2 months old and had undergone linear cranieectomies for premature closure of the sagittal suture. Postoperative pneumography was normal, and he had not shown evidence of hydrocephalus after 10
months of observation. The other was 5 months old and convalescing from bilateral craniectomies for subdural hematomas. Here, too, the ventricles were of normal size, and there had been no evidence of postoperative increased pressure for 6 months.

RISA cisternography in both controls was uniform (Fig. 1). The isotope diffused cephalad from the site of injection, reaching the basal cisterns of the posterior fossa within 20 min. In 60 min the chiasmatic, ambient, and quadrageminal cisterns were visualized, and by 2 to 3 hours all the basal cisterns were completely demonstrated by the isotope. After 4 to 5 hours the activity in the cisterna magna began to recede, and there was a diffuse subarachnoid pattern over the hemispheres with concentration along the sagittal sinus. Thereafter the amount of activity gradually and uniformly decreased.

**Low-Grade and Compensated Communicating Hydrocephalus.** There were six patients in this category, ranging from 2 months to 12 years of age. Two were completely compensated, having had no increase in head size during the preceding 12 months. Their pressures, as measured by spinal puncture, were within normal range. The other four, also with mild ventricular enlargement, were continuing to show increase in head circumference but at a rate paralleling the curve of the 97th percentile. Isotope cisternography in these six showed no significant deviation of ultimate isotope distribution after 36 hours. Periods of follow-up have ranged from 1 to 2 years in these cases, and none has required a ventriculoatrial shunt.

**Progressive Communicating Hydrocephalus.** This category included four infants, 2, 4, 5, and 8 months of age. Meningitis was the probable etiology in three. They required frequent ventricular taps to control pressure prior to testing. In all four there was accumulation of the RISA in the lateral ventricles within 30 min. The ventricular activity became diffuse by 60 to 90 min and persisted in dense concentration at 24 hours (Fig. 2). Diffusion into the basal cisterns and over the hemispheres was sparse or absent.

This ventricular pattern was similar to that seen in nine adults with communicating hydrocephalus and normal CSF pressures, as measured in the lumbar space. In the adults, however, the appearance of the isotope within the ventricles was relatively delayed.

**Communicating Hydrocephalus, Post-**
Shunting. A 2-year-old child with moderate communicating hydrocephalus, whose ventriculoatrial shunt had functioned for 6 months, was scanned after the cardiac end had become obstructed. At the time she had slightly increased pressure as judged by tension of the fontanel. The isotopic pattern in this child conformed to that of the normal controls.

Four shunt-dependent severe communicating hydrocephalic children were scanned following insertion of shunts. Two of these had had preoperative scans, and in each there had been rapid ventricular filling. With the shunts functioning normally the isotope patterns appeared to be delayed through the basal cisterns, but after 24 hours the normal hemispheric pattern was seen (Fig. 3).

Aqueductal Obstructive Hydrocephalus. We studied eight infants and children with pneumographically verified aqueductal occlusion. Six of these were scanned only once, weeks to months following insertion of shunts. Their patterns were variable with two showing prolongation of cisternal activity and variability in spread over the hemispheres, and two others showing normal scans. Only two of the six showed definite evidence of a persistent block in the subarachnoid spaces (Fig. 4).

Two infants were scanned both before and several days after successful placement of ventriculoatrial shunts. The first, who was 4 months old, showed retardation of diffusion of the RISA over the hemispheres both pre- and postoperatively with no significant difference between the two scans. During the preoperative scan, his intracranial pressure was elevated. The other infant showed a striking difference. She was 2 weeks old and had severe progressive hydrocephalus with marked ventricular enlargement. The preoperative scan, taken when the fontanel was bulging, showed significant retardation of diffusion with little isotope progression beyond the basal cisterns even at 12 hours. Two weeks following insertion of a shunt, when the fontanel was depressed and her head decreasing in diameter, quite the reverse was demonstrated. There was rapid diffusion of the isotope into expanded subarachnoid spaces over the hemispheres (Fig. 5).

Complications. One child had a febrile period with minor meningeal irritation lasting 3 or 4 days. No late complications have developed in any of our cases in periods of follow-up ranging from 1 to 3 years.
Discussion

Our experience is sufficient to conclude that isotope cisternography with RISA in infants and children is relatively safe and provides a definition of the extraventricular CSF pathways adequate for identification of the major cisterns. The diffusion characteristics of RISA during the first 24 hours, with scanning intervals of 30 to 60 min initially and 2, 4, 8, 12, and 24 hours later, suffices for defining the differences seen in hydrocephalus.

For determination of intracranial pressure during the scanning period we relied upon single measurements at lumbar puncture and clinical estimation, particularly tension of the anterior fontanel. Based upon these it was apparent that the size of the basal cisterns and hemispheric subarachnoid space was greatly influenced by the intracranial pressure at the time of scanning. When the pressure was high, these spaces were considerably reduced. When the intracranial pressure was approximately in a physiological range, the pattern of diffusion of the isotope in the extraventricular space could be classified as normal, delayed, or showing a persisting block. Determination of more subtle differences in diffusion is probably not within the capability of the technique.

Cases with severe communicating hydrocephalus, following restoration of a physiological pressure by shunting, generally showed a delayed pattern consistent with partial anatomical obstruction in the distal basal cisterns. It was not proven in these cases, by postoperative ventriculography, that the aqueduct had continued to remain

Fig. 3. Pre-shunt (left) and post-shunt (right) cisternography in an infant with severe communicating hydrocephalus. Lateral views (top) and anteroposterior views (bottom) show diffuse ventricular activity at 5 hours in the pre-shunt state and wide cisternal distribution in the post-shunt scan.
patent in all, but the failure of the isotope to pass into the ventricles was probably significant. The aqueductal obstruction cases showed all these patterns, normal, delayed, and persistent block, after restoration of physiological pressure by shunting.

The potentially useful clinical information to be gained from isotope cisternography, which correlates with other parameters in infantile and childhood hydrocephalus, can be summarized as follows: A normal study in communicating hydrocephalus suggests that

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**Fig. 4.** Persistent retardation of RISA distribution with prolonged cisternal activity in a patient with aqueductal stenosis (artist's sketch).

**Fig. 5.** Pre-shunt (left) and post-shunt (right) anteroposterior views 2 hours after lumbar injection of RISA in an infant with aqueductal stenosis. A radioactive headmarker was used for the scan on the left.
the process is compensated or arrested and that surgical shunting is not indicated. Passage of the isotope into the ventricular system indicates severe progressive hydrocephalus and the need for surgical shunting. One may infer that ventriculocisternostomy will be successful in some cases of congenital aqueductal atresia showing adequate formation of an extraventricular CSF space without a block.

**Summary**

Scintillation camera studies of the distribution of intrathecally injected RISA were performed in a series of infants and children with hydrocephalus of diverse etiology and severity. Scanning intervals at ½, 1, 2, 4, 8, 12, and 24 hours defined all the significant differences in intracranial diffusion patterns. Increased intracranial pressure, during the time of scanning, limited diffusion of the isotope beyond the preponite cistern. Correlations between clinical parameters and the distribution of isotope are as follows. When the hydrocephalus is arrested or compensated the studies are normal. In the presence of progressive communicating hydrocephalus there is diffusion of the isotope into the ventricles when the pressure is elevated, and delayed diffusion into the anterior basal cisterns and hemispheric subarachnoid space when the pressure falls within a physiological range. Cases with aqueductal atresia may have complete, incomplete, or no evidence of blockage in the extraventricular CSF space when the intracranial pressure is normal.

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**References**


