Radioisotope evaluation of experimental hydrosyringomyelia

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Kaolin-induced hydrosyringomyelia in dogs has been investigated by radioisotope ventriculography using both cerebrospinal fluid radioassay and scintigraphy. The hydromyelic central canal can be differentiated from the spinal subarachnoid space by scintigraphy. Serial studies show that hydromyelia arises rapidly to decompress the associated hydrocephalus in surviving animals. Syringomyelia, after a delayed onset, originates from the enlarged central canal. Radioisotope ventriculography may be a useful clinical aid in the diagnosis of hydrosyringomyelia.

Key Words • hydrosyringomyelia • syringomyelia • hydromyelia • radioisotope ventriculography • hydrocephalus

Kaolin-induced hydrosyringomyelia is an established experimental model in the investigation of human hydrosyringomyelia. It was originally believed to be secondary to ischemia, but it may arise from disordered ventricular hydrodynamics. Once established, kaolin-induced hydromyelia decompresses the associated hydrocephalus. As animals normally die within 2 to 3 days of acute hydrocephalus, compensatory hydrosyringomyelia should develop rapidly in survivors.

In this report, the sequential changes in the central canal after kaolin-induced hydrocephalus are analyzed by radioisotopic ventriculography. First, however, the ability to differentiate the hydromyelic central canal from the spinal subarachnoid space by this technique is confirmed by both radioassay and scintigraphy. The potential clinical application of radioisotope ventriculography to the diagnosis of human syringomyelia is discussed.

Method

Following the technique described by McLaurin, et al., we induced hydrosyringomyelia in 12 adult mongrel dogs, weighing 8 to 15 kg, by intracisternal injection of 250 mg of kaolin mixed in 1 cc of cerebrospinal fluid (CSF). Three healthy adult mongrel dogs, weighing 6 to 9 kg, were used as controls.

Each study was performed under intravenous pentobarbital anesthesia (30 mg/kg). Through a burr hole we injected into the right lateral ventricle 2.0 mCi of high specific activity $^{99m}$Tc human serum albumin (HSA), in an isotonic solution (0.91 mg albumin/1 cc). A CSF radioassay was done using an
FIG. 1. Radioisotope activity shown by CSF radioassay in a dog with hydromyelia of 3 weeks' duration. The radioisotope appears rapidly within the cervical central canal, but no activity was present in the lumbar subarachnoid fluid. Cervical subarachnoid fluid was insufficient for sampling. Time = minutes after $^{99m}$Tc HSA injection.

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Cerebrospinal Fluid Radioassay

Two dogs with kaolin-induced hydromyelia of 4- to 12-weeks duration underwent cervical and lumbar laminectomies. The central canal was exposed and cannulated with a No. 25 butterfly needle at the cervical level in one animal and at both cervical and lumbar levels in the other. The lumbar subarachnoid space was cannulated in both animals with a No. 25 butterfly needle. After samples of both central canal and subarachnoid fluid were taken, we injected 2 mCi $^{99m}$Tc HSA into the lateral ventricle of each animal. We then took 0.1-cc specimens of fluid from the central canal and the subarachnoid space at 5, 15, 30, 45, 60, 120, 150, and 180 minutes after radioisotope injection. When the experiment was complete, 20 $\mu$l of each specimen were pipetted and counted for 60 seconds by scintillation spectrometry. Each specimen was counted twice and the mean value taken. Correction for isotope decay during the counting procedure was not made.

The radioisotope flowed from the ventricle selectively down the central canal (Figs. 1 and 2) confirming the previous work by Eisenberg, et al., in kaolin-treated cats. Scintigraphy at this time revealed the hydromyelic central canal as a narrow band of spinal activity extending from the cervical to lumbosacral regions.

Scintigraphy

In Study No. 1, an attempt was made to differentiate the hydromyelic central canal from the spinal subarachnoid space using the routine gamma scintillation camera. This experiment was designed to evaluate the potential diagnostic use of radioisotope ventriculography. In Study No. 2, the serial automatic gamma scintillation well counter,* and scintigraphy was performed 2 hours after $^{99m}$Tc HSA injection with a gamma scintillation camera.†

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†Picker Dynacamera 2C manufactured by Picker Corporation, 595 Miner Road, Cleveland, Ohio 44143.
changes in the central canal after intracisternal injection of kaolin were explored. These sequential studies were performed to compare the onset of hydrocephalus with that of hydromyelia.

**Study No. 1.** Radioisotope ventriculography was performed in four animals with established hydromyelia of 4 to 12 weeks duration followed by scintigraphy of the hydromyelic central canal. Then lumbar intrathecal injection of 0.5 mCi $^{99m}$Tc HSA was followed by scintigraphy of the spinal subarachnoid space. With the low energy, ultrafine resolution, gamma scintillation collimator, the central canal was clearly distinguished from the subarachnoid space in all four animals. The former was smaller in diameter while the latter showed filling of the spinal nerve root sleeves (Fig. 3). Magnification with the pinhole collimator emphasized these differences (Fig. 4). Activity within the subarachnoid space obscured the simultaneous differentiation of the central canal.

**Study No. 2.** Eight mongrel dogs were injected with 250 mg of kaolin intracisternally by McLaurin’s technique. Radioisotope ventriculography studies were performed 6, 30, 60, and 120 hours after kaolin injection. Scintigraphy was performed 2 hours after radioisotope injection in each case. These radioisotope studies were also performed in the surviving kaolin-treated dogs 4 to 12 weeks after kaolin injection, by which time intramedullary cavitation had been shown to be present. Three normal dogs were used as controls.
Results

Controls

Filling of the ventricles, basal cisterns, and rostral cervical subarachnoid space was seen in all three control animals. No spinal activity occurred below midcervical levels in either the subarachnoid space or the central canal.

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6-Hour Study. Eight animals had enlarged ventricles with no filling of the basal cisterns. There was marked activity within the fourth ventricle and cervical central canal in six animals (Fig. 5 A), one of which had central canal activity to the lumbosacral region. Two animals had no cervical central canal activity; one of these died of acute hydrocephalus 24 hours after the kaolin injection.

30-Hour Study. Six of the seven survivors showed filling of the hydromyelic central canal 30 hours after the kaolin injection (Fig. 6).
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In five, the canal extended to the lumbosacral region, and in one animal to a mid-thoracic level. Imaging of the lumbosacral region revealed communication between the distal hydromyelic central canal and the lumbosacral subarachnoid space to some extent in five animals (Fig. 6). The seventh dog, with no hydromyelia evident at 30 hours, died of acute hydrocephalus within 48 hours of kaolin injection (Fig. 7 A).

60-Hour Study. All six survivors had pronounced activity within the central canal extending to the lumbosacral region (Fig. 5 C). Distally, communication existed between the central canal and the subarachnoid space. The ventricles remained somewhat larger than normal.

120-Hour Study. Further increase in central canal activity was seen, representing either increased flow through or increased size of the central canal (Fig. 5 D).

4- to 12-Week Study. In contrast to the even distribution of isotope within the hydromyelic central canal in the above studies, the chronic kaolin-treated animals showed focal areas of increased spinal activity at cervical and thoracic levels, communicating with the central canal. These loculated areas of ac-

Fig. 7. Results of 99mTc ventriculography shown by scintigraphy, with a fine collimator, 30 hours after kaolin injection. A: Failure of hydromyelia to develop; the dog died of hydrocephalus. B: Hydromyelia shown in a dog that survived.

Fig. 8. Results of 99mTc ventriculography shown by scintigraphy, with a fine collimator, 4 weeks after kaolin injection. The spinal film composite shows three syrinxes (cervical, cervicothoracic, and thoracic) arising from the hydromyelic central canal. Distally, the communication between the hydromyelia and the lumbosacral subarachnoid space is seen (arrow).
tivity were confirmed as syrinxes at autopsy (Fig. 8). Syrinxes were seen in all six animals studied after 4 weeks.

**Discussion**

The development of both hydrocephalus and spinal cord cavitation following experimental kaolin-induced occlusion of the fourth ventricular outlets have been well documented by McLaurin, et al. These authors also demonstrated communication in some animals between the hydrocephalic ventricles and spinal cord cysts, by both histopathological study and Pantopaque ventriculography. These findings have since been confirmed by later investigation using spinal central canal occlusion, ventricular perfusion, and serial histopathological studies in animals injected intracisternally with kaolin.

Kaolin hydrosyringomyelia, initially believed to be of ischemic origin, has more recently been shown to arise from the associated hydrocephalus. By radioisotope ventriculography and perfusion studies, Eisenberg, et al., have shown that hydrosyringomyelia is the primary means of ventricular decompression in kaolin-injected cats. Our results support Eisenberg's findings. Hydromyelia developed within 60 hours of occlusion of the fourth ventricular outlets as shown by radioisotope ventriculography. Failure of hydromyelia to develop was associated with early death of the animal from acute hydrocephalus. In addition, radioisotope ventriculography showed that the hydromyelic cavity communicated distally with the spinal subarachnoid space, a feature previously noted by Becker, et al., in canal occlusion experiments. These observations suggest that experimental hydromyelia develops as an essential compensatory mechanism, altering the hydrocephalus from obstructive to communicating in nature.

Development of kaolin-induced hydrosyringomyelia, while stabilizing ventricular size, is followed by progressive spinal cord pathology. Extensive intramedullary extravasation of CSF occurs, a feature that shows similarities with human syrinxes. Early kaolin-induced syrinxes show little reaction on histology, which Greenfield stated is characteristic of recently dissected areas of human syringomyelia. More chronic kaolin syrinxes develop reactionary changes both in the cyst walls and around the vessels, similar to areas of the human syrinx. The evolution of these kaolin-induced syrinxes from the hydromyelic central canal was clearly seen by radioisotope ventriculography, confirming previous studies of the histopathology.

We believe that the kaolin model demonstrates the sequence of events described by Gardner in the hydrodynamic theory of human dysraphism and syringomyelia. Gardner has proposed that early fetal hydrocephalus, from obstruction of the rhombencephalic roof, distends the central canal (hydromyelia), with either prenatal rupture of the spinal cord (myelocele), or postnatal intramedullary cavitation (syringomyelia). While controversy remains over the Gardner hypothesis, communication between the ventricles and spinal cord cysts has been demonstrated in a number of human cases by a variety of means including Pantopaque ventriculography. Furthermore, successful treatment of human syringomyelia and myelodysplastic hydromyelia by ventricular shunting has been reported, even in the presence of normal-sized ventricles.

Diagnosis of hydrosyringomyelia by Pantopaque ventriculography, while definitive, may be complicated by exacerbation of neurological deficits or by acute hydrocephalus. Consequently, a potentially safer method of demonstrating the ventriculohydromyelic communication prior to treatment might be helpful. Both radioisotope ventriculography and cisternography have been employed in cases of human syringomyelia and myelodysplastic hydromyelia, but they have not gained widespread diagnostic use. In this experimental study, we have found that radioisotope ventriculography with routine scintigraphy generally demonstrated the ventricular-hydromyelic communication prior to treatment.

In clinical practice, cases of syringomyelia with partial communication across the fourth ventricular roof probably cannot be diagnosed by this technique as simultaneous activity in the spinal subarachnoid space obscures the central canal. Our results with
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radioisotope ventriculography as a diagnostic aid in human myelodysplasia are reported elsewhere.\textsuperscript{13}

References


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