PERIPHERAL EXTENSION OF RADIOPAQUE MEDIA FROM THE SUBARACHNOID SPACE

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INTERPRETATION of pantopaque myelograms rarely presents difficulties when the examination is properly conducted. Occasionally, an atypical pattern may be obtained as a result of faulty technique or of anatomic abnormality. Peripheral extension of the medium along the spinal nerves is unusual but occurs often enough to justify special consideration. Such peripheral extension has been noted by others\(^{1-3}\) using pantopaque or other myelographic media, and has been observed in 4 of the first 200 pantopaque myelograms done at Strong Memorial Hospital.

In this paper these four atypical myelograms are discussed in relation to a variety of observations on experimental contrast neurography which have been reported elsewhere\(^{4-6}\). It seems evident that both clinically and experimentally a medium escapes along the peripheral nerves only under distinctly abnormal circumstances. Accordingly, the collective results have little bearing on whether there is a direct communication between the subarachnoid space and the perineural spaces of peripheral nerves. They do, however, show that a connection can be established and this may be significant in relation to local anatomic anomalies, pathologic processes, and injection irregularities.

CLINICAL CASES

Extension of the pantopaque outside the normal confines of the subarachnoid space was encountered in all four cases in the course of routine myelography.

CASE 1 (S.M.H. No. 232664).—Immediately after the medium was injected it was seen fluoroscopically to flow out of the lumbar cistern and to globulate on the left side (Fig. 1, A). These globules disappeared when the patient was tilted head down, suggesting that diverticula were being emptied. When laminectomy was performed for removal of a protruded disc at the fourth lumbar vertebra, the reason for the unusual myelogram was clearly demonstrated. The first and second roots were seen to be encased in large diverticular extensions of meninges that contained fluid which could be emptied on compression (Fig. 1, B).

CASE 2 (S.M.H. No. 219584).—Since routine radiographs showed pronounced changes from the second to fourth lumbar vertebrae, consistent with a diagnosis of Charcot spine, lumbar puncture for the injection of pantopaque was made at the fifth lumbar interspace. After injection the medium did not flow as the patient was postured. From the radiograph (Fig. 2) taken after 3 c.c. of pantopaque had been injected it was evident that the tip of the lumbar puncture needle was off to one side of the spinal canal, and that the medium had extended bilaterally for short distances along several nerve roots. The pantopaque could not be aspirated at the time of the initial injection but was removed without diff-

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Fig. 1.—A, Myelogram showing the filling of diverticula in Case 1. B, Operative exposure showing the anatomic defect visualized in the myelogram.

Fig. 2.—Myelogram showing the extension of pantopaque for short distances along the nerve roots in Case 2. Complete subarachnoid obstruction is shown at the upper margin of the opaque column. The lumbar puncture needle is placed eccentrically and appears to be lodged in the first sacral nerve root.
cultly twelve days later by means of a second lumbar puncture. Determination of the spinal fluid protein in the first sample gave a value of 90 mg. per cent.

**Case 3 (S.M.H. No. 173025).—Lumbar puncture was performed at the third inter-

space, 7 c.c. of spinal fluid were withdrawn, and 5 c.c. of pantopaque injected. On fluoros-
copy most of the medium was seen to be distributed along the nerve roots as shown in
Fig. 3, A, but a small amount still flowed freely on manipulation of the patient. No at.
tempt was made to aspirate any of the medium. Check radiographs taken at various intervals (Fig. 3, B, C, and D) over a period of five months showed that the medium apparently was fixed in position, that the relative distribution remained the same, and that the amount decreased significantly.

Case 4 (S.M.H. No. 33594).—Only a few drops of spinal fluid were obtained at myelography but the medium was injected nevertheless. The distribution that obtained immediately after the injection is shown in Fig. 4, A. Under fluoroscopic visualization the medium was seen to flow easily in a cephalad direction but when the lumbosacral region was examined, the medium was seen to have escaped along the fifth lumbar and first sacral roots on the right side. These areas appeared fairly broad and irregular in outline. None of the medium could be aspirated at the end of the examination. Radiographs taken two days later visualized the distribution shown in Fig. 4, B. Fourteen months later all the medium along the nerve tracts had disappeared, and only a small amount—estimated at 0.2 c.c.—was present at the termination of the lumbar sac.

**EXPERIMENTAL STUDIES**

Experiments were carried out in rats, rabbits, and dogs to study the behavior of radiopaque media in peripheral nerves and in the subarachnoid space. The extension of fluid iodinated compounds of varying viscosities was studied.
both visually and radiographically after injection under measured pressures into the perineural spaces of peripheral nerves and into the subarachnoid space. Many of the experiments were acute, and in these it was frequently desirable to tint the media by the addition of small amounts of printer's ink. In the acute experiments iodobenzene was usually used, and in the chronic studies pantopaque was employed.

Fig. 5.—Experimental neurogram in a dog showing extension of iodobenzene in a single fasciculus to a point of extravasation at the lumbosacral plexus. Following this break-through, the medium extends both to the subarachnoid space and centrifugally along another portion of the nerve.

*Extension of Media Injected Into Peripheral Nerves.*—After cannulation of a single fasciculus in the common peroneal nerve at the popliteal space, an injected medium flowed easily both proximally and distally, and remained confined to the perineural spaces (see Fig. 6). The extension was visualized radiographically as a single line or a series of parallel fine lines extending from the point of injection to the subarachnoid space proximally and into the midfoot distally. Some pressure was required for the injection and this varied with both the species and the area of the nerve being traversed by the medium. In the nerves of rats and rabbits, pressures of the order of 50 to 80 mm. of Hg were required to cause extension, whereas in dogs pressures ranging from 96 to 138 mm. of Hg were necessary. Penetration of the medium into the sub-
arachnoid space occurred only under considerably greater pressure, and in
dogs took place when pressures of 165 to 200 mm. of Hg were applied. Ex-
travasation of a medium occurred after inaccurate injection, on the develop-
ment of excessive pressure, and, occasionally, when the medium reached a
region of plexus formation in the nerve. An example of the extravasation
at a plexus is shown in a radiograph (Fig. 5) obtained after iodobenzene had
been injected in a single fasciculus of a dog nerve. As is shown in the illus-
tration the medium traveled proximally to the nerve plexus where extravasa-
tion occurred. From this site the medium extended in two directions under
the same injection pressure. A portion continued on into the subarachnoid
space and a second column of medium returned in a centrifugal direction in
another area of the nerve.

Fig. 6.—Sections from a rabbit nerve following injection of iodobenzene tinted with
printer's ink: A, just above site of injection in the peroneal nerve at the knee, and B, at
level of dorsal root ganglion. The medium is centrally located in the peripheral portion of
the nerve but comes to lie in perineural clefts at the level of the ganglion.

There was never evidence of rapid spontaneous flow of the media in the
perineural spaces but in chronic experiments where pantopaque was used a
very slow centripetal motion of the medium was evident some weeks after
the injection. In passing it may be noted that iodobenzene was very irritating
to nerves and produced severe damage, whereas pantopaque appeared to be
very satisfactory for chronic experiments.

Microscopic sections at various levels of the nerves and roots showed that
at the site of injection the carbon-tinted media occupied the central portion
of the endoneurium. Followed centripetally, the injected mass occupied a
more peripheral location in the fasciculus until, at the lumbar plexus, it appeared in clefts on the inner surface of the perineurium or the perineurial septa still confined to a small portion of the total sheath extent. From these clefts the medium escaped into the subdural space, and, apparently by breakthrough, into the subarachnoid space. Subarachnoid entrance always occurred through the perineurium and never in the periaxonal tissues. Sections of rabbit nerves illustrating certain phases of the passage of a medium are shown in Fig. 6, A and B.

![Image](image_url)

**Fig. 7.**—Filling of peripheral nerves of a dog from the subarachnoid space by the application of relatively high pressure. The lumbar cistern has been dissected away to show more clearly that the iodobenzene is present in several nerves and the filum terminale.

**Behavior of Media Injected Into the Subarachnoid Space.**—In the course of the development of pantopaque, intrathecal injections were made in ninety-four dogs, and many of the animals were kept under observation for one year or more. Of this group, serial radiographs were made on twenty-three dogs at varying intervals, but in no instance was there evidence of the medium extending out of the normal confines of the spinal subarachnoid space along the peripheral nerves. On the other hand there was a smaller group of dogs in which iodobenzene was introduced into the subarachnoid space, and in this...
group the result was somewhat different. The introduction of iodobenzene was always fatal, but in most of these dead animals the medium extended down the lumbar peripheral nerves for distances of 2 to 4 cm. after an interval of one or two hours.

Fig. 8.—Radiographs of the head of a dog taken five hours after intracranial injection by cisternal puncture of ethyl iodophenyvalerate, a substance similar physically to iodobenzene. The medium has extended through the cribriform plate into the nasal and cervical lymphatics. In the dorsoventral view the valve structures of the lymphatics are visualized.

In another series of experiments media were instilled into the intracranial subarachnoid space under physiologic pressures. Rapid extension along the optic nerve and through the cribriform plate was observed. In the latter case the media flowed into the nasopharyngeal lymphatics, cervical lymph nodes,
and periesophageal lymphatics, and were recovered from the nasal secretions. The final stage of one such experiment, in which ethyl iodoethylvalerate was used, is shown in Fig. 7. Most of the media used for this purpose were too irritating for chronic studies, but pantopaque did not appear to have deleterious effects.

Experiments were devised, also, to illustrate the behavior of media under increased pressure in the lumbar subarachnoid space. The lumbar cisterns of dogs were cannulated and media run in under increasing pressures. No extension was observed until the lumbar cistern was ligated 5 cm. proximal to the cannula and the pressure elevated to over 200 mm. of Hg. Extravasation of media took place long before this pressure was reached, and in only one instance was extension beyond the dorsal root ganglion observed in a living dog (Fig. 8).

DISCUSSION

The experimental observations reported here shed some light on the behavior of radiopaque oils in the subarachnoid space. Under normal pressures a distinct difference was apparent between the behavior of media in the intracranial and in the intraspinal spaces. From the intracranial space, the materials exited readily and under physiologic pressure through the cribiform plate into the nasal secretions and cervical lymphatic system. From the lumbar cistern, extension of the radiopaque materials was never observed under physiologic conditions but did occur into the perineural spaces when excessive pressures were applied or the animal was killed.

The peripheral injection experiments serve to clarify somewhat the structure and communications of the perineural spaces. They appear to be connective tissue planes organized from the dural-perineural sheath. These form discrete channels in such a fashion as to subdivide the progressively branching nerve into longitudinal compartments supporting axis cylinder extensions. Evidence favoring a physiologic current of fluid in these spaces was not obtained as media extended only under direct injection pressure, or, very slowly, in an active animal. In the latter case, flow occurred centripetally or in the opposite direction to that which would be expected if cerebrospinal fluid normally entered perineural channels from the subarachnoid system. Further, such anatomic communication was not observed in serial sections of the dural penetrations of many roots. Finally, media injected peripherally always entered the subarachnoid space from dural-perineural clefts apparently by breakthrough across the arachnoidea.

Clinically, evidence is lacking for physical communication normally between the spinal subarachnoid space and peripheral nerves. The four abnormal myelograms show that extension of media can occur, and this suggests that communication does develop under unusual circumstances.

Case 1 presented a definite anatomic abnormality. It was notable here that, although the medium extended well beyond the normal confines of the subarachnoid space, it did not continue out the nerve in the perineural spaces. Since some variation in size of axillary pouches is normally seen in myelog-
raphy, it is conceivable that unusual prolongations may account occasionally for short extensions of injected media, but never for actual communication with the perineural spaces.

In Case 2 there was a complete subarachnoid block only a little above the point of injection and the termination of the lumbar cistern. Abnormal factors to account for the uniform extension of the medium into the nerve roots include (1) anatomic changes which may have developed as a result of a chronically obstructed subarachnoid space, (2) pressure alterations produced by the injection of additional fluid into a small closed space, and (3) injection directly into a nerve root rather than into the subarachnoid space. The first and second of these possibilities seem to offer the most plausible explanations.

In Case 3 there was no unequivocal evidence that most of the pantopaque was ever in the subarachnoid space. The original myelogram showed the opaque oil in essentially the same areas as the final one taken five months later. The most probable explanation in this case is, therefore, that the medium was injected to a large extent outside the subarachnoid space, possibly subdurally.

The radiographic evidence in Case 4 indicated that the injection was made well outside the main body of the subarachnoid space, presumably into the perineural spaces of a nerve root. As a result the pantopaque extended into the subarachnoid and subdural spaces, and peripherally to the lumbosacral plexus. From the latter area it extravasated into other perineural spaces to fill portions of all the nerve trunks uniting at the plexus. Support for this concept can be derived from the fact that the nerves filled only on the side of the injection. This behavior is analogous to the results obtained experimentally in numerous injections of peripheral nerves, which is well illustrated by Fig. 5.

These clinical experiences are similar to other published cases about which there has been speculation concerning the mode of absorption or escape of media from the lumbar cistern. It has been suggested by Maltby and Pendergrass that "... rapid escape along the nerve roots seems to indicate passage through pre-existing channels. ..." Others have considered from experimental and pathologic evidence that such mechanisms function prominently in the absorption of cerebrospinal fluid. The evidence collected from the clinical cases and laboratory experiments reported here does not support a free communication between the subarachnoid space and the perineural spaces of peripheral nerves under normal conditions. The results indicate rather that injected radiopaque oils escape from the lumbar subarachnoid space only under distinctly abnormal circumstances such as local anatomic abnormality or injection irregularity.

SUMMARY

In a series of 200 consecutive myelograms, four cases were encountered in which the injected pantopaque extended outside the normal confines of the subarachnoid space apparently along the nerve roots. These phenomena have been correlated with results obtained experimentally in the study of the ex-
tension of contrast media in the perineural spaces of peripheral nerves both by direct injection and from the subarachnoid space.

It was concluded from these observations that, clinically, pantopaque extends out of the subarachnoid space only under distinctly abnormal circumstances such as local anatomic abnormality or injection irregularity. The experimental evidence indicated that the perineural spaces are merely connective tissue planes in peripheral nerves which communicate only indirectly with the subarachnoid space. There was no indication from these observations that such spaces function in the normal circulation of cerebrospinal fluid.

REFERENCES