OBSERVATIONS ON OPAQUE MYELOGRAPHY OF LUMBAR DISC HERNIATIONS

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In recent years there has been considerable attention focused on herniated discs. This paper will refer to opaque myelography with the use of lipiodol and pantopaque for the demonstration of herniated discs in the lumbar region, and will be confined to a discussion of some aspects of procedure and interpretation.

1. Procedure

Introduction of the oil

The site chosen for introduction of the oil should be at some level other than that of suspected herniation; otherwise the subarachnoid space may not be readily entered. Deformity of the oil column may be produced by the needle and if so, it is best that it occurs remote from an area of probable herniation. As most herniations are at L4-L5 or L5-S1 levels, it has been found most satisfactory to introduce the needle between L2 and L3 or between L3 and L4. With puncture at higher levels one risks damage to the spinal cord. The level chosen may be important in the removal of the oil, a procedure to which reference will be made again.

The needle chosen should be sharp and of moderately short bevel. A dull needle may push the dura in ahead of it; a long-bevelled one may be simultaneously in the subarachnoid and sub-dural or extra-dural spaces, so that although cerebro-spinal fluid is aspirated the oil may be injected sub-durally or extra-durally.

To avoid the accidental injection of oil into the extra-dural or sub-dural space, one may first inject 0.5 c.c., insert the stylet of the needle and then without manipulating the needle or turning the patient, carry out a brief fluoroscopic examination.

A rapid flow up or down the spine when the patient is tilted indicates that the injection was made satisfactorily and that the remainder may then be put in. Unless the fluoroscopic screen has a locking device to hold it at a desired level it may touch and displace the needle at the time the initial 0.5 c.c. is examined.

Quantity of oil used

Three cubic centimetres of oil are adequate for examination in almost all cases. I would prefer 5 to 6 c.c. or even a larger quantity at times, but limitation of supply has prevented its use. The larger quantity requires only slightly more time for extraction, as it is usually the last 0.5 c.c. which provides difficulty in removal. The larger the quantity used the more extensive the area that is completely filled when the patient is standing. With quantities less than 3 c.c. even the lumbo-sacral disc may not be bridged in this position. In practice, complete filling of the subarachnoid sac in the area examined is not necessary for the recognition of herniated discs, for with the patient prone the oil lies anteriorly where the deformity is greatest.

With a given quantity of oil its thickness as it lies in a layer along the spine when the patient is prone depends upon the amount of lumbar lordosis present. With considerable lordosis the oil will remain in a compact mass. If the spine is flat or slightly kyphotic it will spread over a long distance and will be relatively shallow and narrow. In the latter instance added quantities of oil will not be of assistance in deepening the layer so long as the patient remains horizontal.

Leaving the needle in place during fluoroscopy

There are advantages and disadvantages of leaving the lumbar needle in place during the examination. It is advantageous in that it minimizes trauma and shortens the examination, for a second puncture is then not usually required for the extraction of the oil. The shadow of the needle provides a ready marker with which one can identify the vertebral level of a defect and its appearance is an indication of the degree of obliquity of the spine. One disadvantage is that it increases the object-screen distance with some resulting blurring of the image and an increase in the stray radiation to which the examiner is exposed. More care is required in the examination lest the screen displace or even break the needle. Finally the needle may rarely cause deformity of the myelogram leading to difficulty in interpretation.

Extraction of the oil

Removal of the oil may be very simple or very difficult, but in almost all cases can be successful. It is preferably carried out with the patient in the prone position. With fluoroscopic observation the table is tilted up or down to bring the oil about the needle. Difficulty in puddling the oil will be experienced with patients who have flat lumbar spines. As with fluoroscopy for diagnosis, it is of assistance in these cases to arch the back with pillows under the chest and thighs.

A common cause of failure is in having the needle placed too superficially so that it lies in the layer of spinal fluid. The oil being heavy lies anteriorly and
visible globule to the needle point. Extraction is particularly difficult when, as sometimes happens, the oil, instead of remaining in a single mass, breaks up into a great number of small globules. Coalescence may sometimes be brought about by having the patient stand on his toes and come down on his heels several times with a jarring effect.

The best site for removal is at the level where it is found on fluoroscopy that the oil can be brought into a compact mass. This will almost always be at some level below the third lumbar segment.

Extraction is often difficult because the nerve roots are drawn against the needle with every attempt at aspiration. In several instances of this almost complete extraction has been brought about by having the patient strain or cough to raise the intraspinal pressure, thus forcing out the oil without aspiration.

Straining, coughing, or deep inspiration may frequently have an interesting effect upon the appearance of the oil column. With each of these the oil may be seen to elongate towards the head and at the same time narrow from side to side. With coughing this is momentary and it quickly resumes its previous shape. If the patient is in a relatively horizontal position the elongation may be as great as 2 inches. This effect may be of use in spreading the oil to a higher level without need for small changes in the degree of tilt of the fluoroscopic table. Occasionally it may shift the oil upwards to a new position where it remains; this may happen if the lumbar curve is shallow, and may be of use in the procedure of extraction.

**2. Interpretation**

Four types of deformity are produced in the myelogram by a herniated disc.

1. Indentation
2. Displacement
3. Block
4. Lack of filling of the axillary pouch or nerve root sheath

**Indentation**

An indentation at the level of the disc space or slightly above or below it, is the most common finding. This may be abrupt or gradual. Typically it is on the antero-lateral surface of the oil column and is visible in antero-posterior, oblique and prone-lateral views (Fig. 1). If the herniation is large the deformity may extend considerably above and below the disc space, if so it is almost always greatest at the disc level. The antero-posterior view is the most useful one; it is unusual to find this projection to be normal when there is a significant deformity in oblique or lateral views.

If the herniation is bilateral an hour-glass deformity may be present. I believe, however, that a similar appearance may be seen with unilateral or central herniation. With the former the constricted part of the oil column usually has an eccentric position, being displaced away from the affected side. Prone-lateral views will show that the indentation affects the front surface as well (Fig. 5).

In the antero-posterior view with the patient prone, a lateral indentation may be seen only momentarily as the oil column moves over the disc space. In this position the oil accumulates in a layer along the anterior part of the subarachnoid sac. As one raises the head end of the table the oil column shifts towards the lumbo-sacral angle where the concavity is greatest and there tends to become more compact and deeper. The added depth may be sufficient to hide a deformity of the margins.
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although it may be still evident as an area of relative radiolucence. An analogy to this masking effect may be seen at the sea-side beach. At the high tide the water’s edge is regular, but as the tide recedes it becomes uneven if rocks are exposed to view (Figs. 2A and 2B).

Fig. 2.

(a) Effect of depth of oil. Large deformity as oil begins to bridge extruded disc, L4–L5.
(b) Same case: Deformity less now that disc space is completely bridged. Case No. 9332.

The normal disc may indent the subarachnoid space slightly and simulate a herniated disc. Simulation is more likely to occur when there is less than normal lordosis for then, with the patient prone the oil column may be so thin that a slight normal bulge of the disc tends to divide it. The deformity as seen in the straight antero-posterior view is of the “hourglass” type, but a prone-lateral view will show that the indentation of the anterior surface is slight, probably not more than 1.5 mm. Multiplicity and symmetry are helpful characteristics with which to distinguish this type of deformity from that produced by a herniated disc.

Fig. 3.


Magnification of defect

All defects due to pressure give one a magnified and distorted impression of the deformity of the thecal sac, for the oil column does not fill the subarachnoid space completely; rather, it shows the space among and about the nerve roots of the cauda equina still patent to the passage of oil. The disparity between the true and apparent size is most readily appreciated in patients with large herniations, particularly where there is partial block, for in these the oil column may be greatly attenuated at the level of pressure (Fig. 3). The roots are crowded together most at the periphery, preventing filling of this area but a core, usually eccentrically placed, is left still patent.

Increase in size of defect with change of position

The deformity in the myelogram may increase in size when the patient is changed from the relatively prone to the upright position. An example of this occurring with a herniation of the lumbo-sacral disc

Fig. 4.

(a) Effect of posture: Patient nearly horizontal. Relatively slight indentation on left.
(b) Same case standing: Partial block now present apparently due to more protrusion. Case No. 8774.

Fig. 5.

(a) Displacement of oil column by herniated L5–S1 disc. Large notch defect also. Case No. 9315.
(b) Prone lateral view (same case): Oil indented from front also. Note third level.
is shown. This is presumed to be due to further extrusion caused by the added weight brought to bear on the disc (Figs. 4a and 4b).

**Displacement of the Oil Column**

The second type of deformity, displacement of the oil column, is infrequently seen. It is present only with very large herniations which also produce a deep indentation or some degree of block. The displacement may be backwards or to one side (Fig. 5).

Displacement of a partially filled root sleeve might occur, but I have not recognised it.

**Block may be Partial or Complete** (Fig. 6)

With either type the side of the herniation if it is unilateral is usually apparent by the shape of the deformity. With partial block an eccentric "hour-glass" appearance may be seen. With complete block the lower end of the oil may be abruptly pointed or cut off transversely. It may be found that the block is considerably above the disc-space level; those unfamiliar with this appearance may suspect a tumour.

Bradford and Spurling report that the dural sac may normally terminate above the lumbo-sacral disc. They point out that symmetry of termination with evenly distributed auxiliary pouches permit

**Henriated Discs with Block**

(A) Partial block due to a large herniated disc L4–L5 on right. Almost complete break in continuity. Case No. 7526.

(b) Partial block due to herniated disc between L4–L5 on right. Case No. 9023.

(c) Complete block due to left-sided herniation L5–S1. Note asymmetrical taper.

**Fig. 6.**

(d) Herniated disc with practically complete block at L5–S1. Pantopaque myelogram. Case No. 3910.

(e) Herniated disc L4–L5 with complete block. Pantopaque myelogram confirmed. Case No. 6229.


**Technical Errors**

(A) Needle deformity. Note the clear area about the needle, between L3 and L4. Patient had herniated disc L5–S1. Case No. 7215.

(b) Needle deformity in another patient with otherwise normal myelogram. Case No. 7274.

(c) Extravascular injection. Much of the pantopaque has left the spine.

**Fig. 8.**

(d) Pantopaque on skin. Blurring of opaque column due to spilling of pantopaque on skin in dressing about needle.


(f) Same case at later examination with successful subarachnoid injection. Note narrower column.
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differentiation from block at the same level. Ordinarily these characteristics are sufficient to make the distinction. Block may rarely, however, show no asymmetry and the normal spine may not show filling of the axillary pouches. One might therefore add as a differential point, the degree of abruptness of termination, a long taper being more characteristic of the caudal end of the normal thecal sac.

LACK OF FILLING OF THE VILLYAR POUCHES OR NERVE ROOT SHEATHS

This may be caused by a herniated disc, but it may also occur normally unilaterally or bilaterally. Its significance is strengthened by the presence of an indentation of the oil column or exceptionally good filling of the other root sleeves. On the other hand, good filling is strong evidence that the portion filled is not being subjected to pressure (Fig. 7).

Root sleeves not shown at the initial fluoroscopy may sometimes be demonstrated at a later examination if the oil is not extracted from the spine.

ERRORS OF TECHNIQUE

Technical errors or artifacts may occasionally be encountered and give rise to difficulty in interpretation.

(a) Needle deformity. An indentation of the oil column may be produced by the lumbar needle if it is left in place during the examination. Presumably the theca is penetrated by only part of the bevel of the needle and is pushed inward, encroaching upon the subarachnoid space. It is interesting to note that in the two examples shown the needle appears to be outside of the subarachnoid space, as there is a clear area about its tip. Yet this was not likely so, as the injection was made with the needle in the position shown. The probable explanation is that in the area of pressure the nerve roots are crowded together sufficiently to force the oil to other areas. The true limits of the subarachnoid sac are thus not shown. As with partial block or indentation deformities from herniated discs one has again demonstrated only its patent portions (Fig. 8).

(b) Extra-dural injection of the oil is ordinarily readily apparent as the oil tends to leave the spine quickly for the paraspinal tissues in the form of irregular small masses or streaks (Fig. 8).

(c) Spilling of the oil on the skin about the site of injection or on a dressing may give a confusing shadow, but it is usually easily recognised (Fig. 8).

(d) Sub-dural injection of oil. Oil injected subdurally may appear to be in the subarachnoid space and since it may move only very slowly or not at all, a block may be thought to be present. One finds, however, that movement is retarded or prevented both up and down the spine, which is very unusual with block. An example is shown (Fig. 8). The larger mass is sub-dural; the small mass at the caudal end of the sac is subarachnoid. Repeat examination three weeks later showed no abnormality.

ESCAPE OF CEREBRO-SPINAL FLUID INTO THE SUB-DURAL SPACE

An unusual appearance presumed to be caused by the escape of cerebro-spinal fluid into the sub-dural space is shown. The pantopaque column was found to be very narrow for a length of about 3 inches (Fig. 9A). Repeat examination 12 days later showed a normal appearance except for a small indentation at the lumbo-sacral level caused by a herniated disc (Fig. 9B). The extreme narrowing above this at the

EFFECT OF SUBDURAL ESCAPE OF C.S.F. ON WIDTH OF OPAQUE OIL COLUMN

With subdural escape of C.S.F.

Diagrammatic cross-section of thecal sac showing opaque oil among and about the nerve roots. Patient upright.

Fig. 10.
cauda equina, leaving only a central core intact (Fig. 10). It appears unlikely that the leakage was extra-dural as this would have had no effect on the patency of the subarachnoid sac. One cannot exclude a sub-dural hematoma.

An appearance suggesting partial block, also ascribed to previous lumbar puncture, is mentioned by Wakeley and Orley, 1938. Their description refers to the upper dorsal spine as the common site, and is not clear whether they are referring to leakage into the sub-dural or the extra-dural space. They suggest that at least a week should be allowed to elapse between a diagnostic lumbar puncture and myelography. The case presented here showed no evidence of block, but gave rise to such an unusual and confusing picture that it is additional evidence in favour of a reasonable time interval between the two procedures.

In conclusion, if in addition to one or more of the four described types of deformity of the myelogram one finds thinning of the disc space, angular scoliosis at the level of the deformity, local osteo-hypertrophic lipping or loss of the normal lordosis, the evidence pointing to a disc herniation is considerably strengthened. The typical clinical findings along with good radiological evidence permit a high degree of accuracy in diagnosis.

REFERENCES

BRADFORD-SPURLING, The Intervertebral Disc, Charles Thomas, publisher, 1941.


The pantopaque used for investigation of the cases described was kindly supplied before being commercially available, through the courtesy of Dr. Stafford Warren, Department of Radiology, School Medicine and Dentistry of the University of Rochester, N.Y.

THE ACTION OF NEUTRONS ON BACTERIA

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INTRODUCTION

It is known that when bacteria are exposed to direct lethal doses of X rays or alpha, beta or gamma rays, the curve obtained by plotting the proportion surviving as a function of the dose is exponential (Lea, Haines, and Coulson, 1936, 1937; Lea, Haines, and Bretschneider, 1941; Herck, 1933; Wyckoff, 1930). It is also known that the effect produced by heavy doses of this order is independent of the intensity at which the dose is administered (Lea, Haines, and Coulson, 1936; Lea, Haines, and Bretschneider, 1941) and of the temperature (Lea, Haines, and Coulson, 1936; Herck, 1934). Different kinds of radiation give rise in the tissues to ionizing particles which produce different densities of ionization along their tracks. If the same kind of biological material is exposed to lethal doses of different radiations in a series of experiments, an attempt can be made to correlate the biological effects of the exposures with the different distributions of ionization which the various radiations produce.

For this reason two types of bacteria of the same strains as those used by Lea, Haines, and Coulson (1936, 1937) in their experiments with alpha, beta and gamma rays, and by Lea, Haines, and Bretschneider (1941) in their experiments with soft X rays, were exposed to lethal doses of neutrons in order to compare the results from each type of radiation. The work was done with Lawrence's 37-in. cyclotron at the Radiation Laboratory, Berkeley, California, in collaboration with Dr. Axelrod, Department of Bacteriology, and Dr. P. C. Aebersold, Department of Physics, University of California.

OBJECT OF EXPERIMENTS

1) To determine the lethal effect of a neutron beam on B. coli and on the spores of B. mesentericus when these organisms are exposed to gradually increased doses of radiation.

2) To compare the results with those already obtained with other types of radiation.

MATERIAL AND METHODS

1) Bacteriological technique before exposure

A suspension of spores of B. mesentericus from vegetative cells and slopes of B. coli were prepared by the late Dr. Haines in the Los Angeles temperature Research Station, Cambridge, and transported to California (via Panama): they were kept in the ship's chill room at 4-5°C. for the 31 days of the voyage, with a further two days in a San Francisco refrigerator before their release could be obtained from the Customs House.

The mesentericus spores were kept in glass distilled water, the density of the suspension being 4 x 10^6/c.c. For irradiation this stock suspension was diluted to contain 10^4/c.c. or 10^5/c.c. The B. coli were grown on nutrient agar slopes for twenty-four hours and the growth was then washed off and diluted to 10^4/c.c. by the napthol blue method. From this dilution a suspension of 10^6/c.c. was prepared for radiation.

2) Radiological technique

The technique of exposure was as follows: 3 c.c. of each suspension in separate glass tubes 1/2 inch in diameter were suspended in the neutron beam a room temperature. Fig. 1 shows the genera

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