A GUIDE TO PNEUMOENCEPHALOGRAPHY

E. Graeme Robertson, M. D.

The techniques to be described have been engrafted, some twenty-five years ago, on the procedure initiated by Dandy in 1919. They have been built upon the use of radiography as a means of providing a running commentary upon the progress of filling, and the establishment of a theory of filling, which was reproduced in vitro (Robertson, 1941, 1946, 1957)*.

APPARATUS

It should always be remembered that apparatus is only a means to an end. The simplest of apparatus may give excellent results in some hands; the most complicated may fail if human care is wanting. It must be stressed, however, that the best of x-ray apparatus is of material assistance.

Fig. 1. Arrangement of two Buckys, chin rest and head rest.

The patient sits in front of a vertical Potter Bucky diaphragm, which may be the type used in general radiography (Figure 1), or part of a head-table (Figure 2). To this are adjustably fixed a padded chinrest, and a curved device designed to straddle the patient's vertex. Thus the head is lightly held in position, while it is possible to take axial** and lateral views without moving the patient's head. The lateral views are taken by means of a mobile Potter-Bucky diaphragm, or by a grid, placed alongside the patient's head.

Many chairs have been described for pneumoencephalography. The crucial point is the maintenance of the alert or anaesthetized patient's position, with the flexed lumbar spine available for lumbar puncture. A simple type of light tubular steel chair is illustrated. It is provided with leather seat and pierced leather back, with leather flaps which fasten around the patient's trunk for support.

** Preparatio**

Preliminary sedation is usual, while anaesthesia may be used for irritable patients and children. The degree of discomfort hardly warrants the general use of anaesthesia. Omnopon 20 mg., scopolamine hydrobromide .6 mg., and morphine sulphate 16 mg. distributed over a period of an hour before the investigation, with larger doses for larger patients, may cause the patient to sleep throughout.

** General Procedure**

The patient sits in the chair with the lumbar spine flexed as much as possible. He cranes his neck forwards, and rests his chin on a padded rest at the bottom

** The word axial is used throughout to denote that the centre-ray is directed along the sagittal plane, whatever angle it may make with the eye-ear line.**

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of the vertical Potter-Bucky diaphragm (either that of a head-table or the standard type used for general radiography). The eye-ear line inclines downwards and forwards 5 to 10°, and a straddling stabilizing device is brought down lightly across the vertex. This arrangement allows of the uninterrupted taking of axial and lateral views, the latter by means of a mobile Bucky or a grid arranged alongside the patient's head.

Lumbar puncture is then carried out, using one or two fine bore needles with short sharp bevels, and two outlets controlled by a three-way tap***. It is important to introduce the needles very slowly, in order to feel the lessening of resistance as first the dura, and then the arachnoid, are pierced. Gas is then injected very slowly through the upper needle, while cerebrospinal fluid is allowed to rise into a glass manometer of 2 mm bore attached to one outlet of the lower needle. If the pressure is normal, the fluid rises to the level of the cisterna magna.

VENTRICULAR FILLING

In most instances the object is to fill the ventricular system, and maximal filling is usually desired.

Theoretical Considerations: The presentation of gas at the vallecula and its flow into the fourth ventricle is purely gravitational, due to the tendency of gas to rise through fluid along available pathways. When the neck is flexed, gas ascends in the subarachnoid space posterior to the cervical spine cord to enter the cisterna magna behind the medulla (Fig. 3 a & b). Some gas may rise directly into the vallecula, but some is directed by the vermis to the dorsal part of the cistern, which then fills before its gas passes, below the sill provided by the vermis, into the fourth ventricle (Fig. 3a). The mechanism of further passage is more complicated, for gas and fluid cannot traverse such a narrow tube as the aqueduct in opposite directions at the same time. The inflow is very rapid. It depends upon the increase of pressure at the head of a column of gas in the median ventricles and the aqueduct. This leads to expansion of the lateral ventricles and inflow of gas. The greater the degree of flexion, the less is the vertical height of a bubble, while the declivity produced by the 3rd ventricle in this position lessens the effective vertical extent of a column (Fig. 4 a & b). Thus the more marked the flexion, the less is the inflow, while the less the flexion the greater the pressure differential (Fig. 4 c). Further, when the head is erect, a downflow of fluid follows the inflow of gas, due to the elastic recoil of the lateral ventricles (Fig. 4 d). In this posture, however, more gas rises into the subarachnoid space ventral to the medulla and is wasted from the point of view of the ventricles (Fig. 3 c). Hence the initial posture is a compromise.

*** Greenfield type, illustrated in Allan & Hanbury's catalogue.
Procedure: After the initial pressure has been measured, some 7 c. cm of gas is injected (over about two minutes) while fluid is allowed from the lower needle at much the same rate, in order to maintain a constant intracranial pressure. As will be indicated later, the maintenance of a constant pressure is quite unnecessary, but slow introduction of gas certainly and relative stability of intracranial pressure possibly contribute to the patient’s comfort.

A lateral film is taken (Fig. 2) and inspected against the safe-light after two minutes development. The gas shadows stand out clearly at this stage, but soon become lost in the general darkening which occurs with further development. At this stage gas is usually seen in the lower ventricles—if not, a further 7 c. cm is injected and lateral and axial films taken.

If all goes well, the interchange is slowly continued and towards the end of filling the head is made almost erect. Lateral and axial films are taken until the ventricles are seen to be satisfactorily filled. When the 4th ventricle is the object of the investigation, the most important films are taken in the erect posture. Lateral and axial views with the head fully dorsiflexed may prove useful in checking the anterior parts of the lateral and third ventricles, while full flexion fills the trigones and occipital horns.

The needles are then removed, and the patient transferred to the supine position.

Fig. 3. Passage of gas through the foramen magnum and posterior fossa.

a. When the head is well flexed, the gas rises through the dorsal cervical subarachnoid space and fills the dorsal part of the cisterna magna before flowing through the vallecula into the fourth ventricle.

b. When the head is less flexed, gas bubbles are directed into the vallecula by the vermis and thus rise directly into the fourth ventricle.

c. When the head is erect, gas may rise directly to the vallecula, but some also passes anterior to the medulla into the ventral subarachnoid spaces.

d. When the neck is dorsi-flexed, gas rises in ventral cervical subarachnoid space and thus flows into the ventral cisterns.
position. The head is gently rocked to equalize the distribution of gas between the lateral ventricles. The following view are then taken:

1. Antero-posterior film with brow uppermost; accurate posturing (without rotation of the skull) and directing the centre ray along the mid-plane of the skull are to be stressed.

The anterior parts of the lateral ventricles are seen on each side with septum pellucidum and 3rd ventricle in the median plane. The lateral ventricles are represented by paired shadows each composed of three clearly defined, but merging shadows. Above is a dense irregular quadrangular shadow which represents the body. Superimposed on this and extending below as a less dense shadow is an elongated triangular shadow which represents the posterior part of the

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Fig. 4. Physical factors with head flexed and erect: a. When the head is flexed, gas displaces fluid downwards through the third ventricle into the lateral ventricle before it flows into the lateral ventricles. A pressure increase at the distal end of the gas in the median passage-ways (equivalent to the effective vertical height of the column A B) causes the lateral ventricles to expand to receive additional fluid and then gas. b. When gas is no longer injected, some remains in the third and fourth ventricles and the aqueduct, a balance being reached between the pressure above and below the distal face of the column of gas in the third ventricle. c. When the head is erect, the rise of pressure at the distal end of the median column (YZ), and therefore the distending force, is greater. d. After all gas has entered, elastic recoil of the brain displaces gas and fluid downwards, and the trap is reset. Thus, for these two reasons, it is possible to obtain a greater filling when the head is erect.
anterior horn. Into this, from the 3rd ventricle, opens the interventricular foramen of Monro. The least dense shadow extends laterally on bulbous fashion and represents the tip of the anterior horn.

The normal septum pellucidum is expected to lie in the median plane of the skull, but anatomical discrepancy may exist and the position of the median plane is rather a matter of judgment than of accurate evaluation. It is possible to imagine the sagittal plane between the crista galli and the mid-point of the occipital protuberance. A ruler placed between the crista galli and the middle of the sagittal sinus at the vertex usually passes through the septum pellucidum. Measurements from the sides of the skull are misleading. Thus diagnosis of the presence of neoplasm, based upon a slight shift of the septum pellucidum alone, may be unjustified. When atrophy exists, the septum pellucidum is often displaced away from the side of the larger ventricle.

Sometimes the septum pellucidum bulges towards one side (Fig. 5), and in one such case it was found to lie in the median line in another film, and bulged towards the opposite side in another. The presence of a large collection of subdural gas over one hemisphere may lead to marked falling away of the ipsilateral ventricle, which again must not be taken as evidence of neoplasm. This is most likely to occur in elderly subjects with marked atrophy.

![Fig. 5. Bowing of the septum pellucidum without clinical significance. In other films of this patient the septum was in the median plane and bowed to the opposite side.](image)

2. Anterior posterior view with temporal horns filled. One shoulder is raised from the table and the head turned to the opposite side, keeping the vertex as far down as possible, and the occiput as high as possible. This runs gas into the trigone and temporal horns. The gas is then loculated in the anterior part of the temporal horn by restoring the head to the brow-up position. The manoeuvre is then more quickly repeated in the opposite direction to loculate gas in the opposite temporal horn. Some, but not all, gas leaves the first-filled horn and, although both usually contain gas, it is difficult to fill them equally. The posture for taking the film is shown in figure 6, and the component parts of
the shadow in figure 7. This is the only view which allows of direct and accurate comparison of the positions of the temporal horns (Fig. 8). Each horn may be filled in turn and photographed separately if their shape is in question (Fig. 9). This is done later after taking lateral views; but completely accurate posturing is easier when the brow is up than when it is turned to one and then the other side.

3.—Either before or after filling the tips of the temporal horns, the tube may be rotated 30° towards the vertex in order to look down upon the roofs of the anterior horns. This view is sometimes valuable when displacements are in question.

4.—A lateral view may then be taken. This shows the superimposed anterior horns, the anterior part of the 3rd ventricle and the tips of temporal horns, and, allowing of direct comparison, may disclose backward displacement which may
not be evident in axial views. It is to be remembered, however, that superimposition is only to be expected if the centre ray passes through the tips of the horns in question, necessitating different centering for anterior and temporal horns.

5.—The patient then turns into the prone position and the following views
are taken:

Postero-anterior view. This view shows the diverging trigones with the darker shadows of the bodies above. A darker circular shadow may be seen in one or other trigonal shadow, representing the occipital horn extending backwards the occiput, along the x-ray beam. These horns are frequently asymmetrical and this must not be adjudged pathological without careful consideration of other factors. Indeed, the trigones, themselves, are often congenitally asymmetrical, and apparent asymmetry may be caused by unequal filling and misdirection of the centre ray. Hence, considerable reserve must be exercised in interpretation of this view.

6.—Lateral view with the occiput uppermost. Again it may be stressed that one occipital horn may be long, while the other is rudimentary or absent. Absence of one shadow does not signify the presence of neoplasm, unless there be also displacement of the corresponding trigone. This view is not of great value and may only be taken in special circumstances.

7.—The patient's head may now be strongly flexed (by lowering the head table). This brings gas into the temporal horns as well as the trigones and a film may be taken with the central-ray directed through the occipital plane. Unfortunately, the tips of the horns are obscured by the petrous temporal bones, but this view may be useful in demonstrating a neoplasm lateral to the temporal horn, trigone and occipital horn. The prone patient's head is then turned to one or other side and gently rocked to transfer as much gas as possible to the uppermost lateral ventricle. It is reasonable to first picture the side on which the pathological lesion is suspected.

8.—A true lateral film to show the profile of the lateral ventricle.

9.—An axial view to show the temporal horn in cross section (Figure 9). The head is slightly dorsiflexed and the centre ray is directed through the nasion along a line between the external canthus of the eye and the upper point of reflection of the temporal skin on the ear. The film is placed behind the head. The cross section of the tip of the temporal horn, with the supracornual cleft above, and the lateral recess lateral to the curved projection of the hippocampus, is thus thrown into the circle of the orbit.

The head is then turned to the opposite side and is again rocked to transfer as much gas as possible from the previously filled ventricle to the now-uppermost one; and 8 and, if necessary, 9 is repeated.

Not all these films are taken in every patient: unnecessary radiography is avoided. Stereoscopic films are sometimes useful, but, with increasing experience, become unnecessary. The overlapping shadows of the lateral ventricles in lateral views may prove confusing at first. As the uppermost part of each ventricle contains gas, the body of the lower ventricle will be seen; while the whole of the upper ventricle will show if it is well filled, but only the trigone and temporal horn if it contains little gas.
A small volume of gas usually passes into the subarachnoid space while the ventricles are filling and no further filling than this may be desired.

**Subarachnoid Space**

One of the virtues of pneumoencephalography is that the subarachnoid space may be demonstrated as well as the ventricles. The pattern of the sulci may be recognized over the hemispheres, and the volume of cerebral tissue between the ventricle and subarachnoid space estimated. Where ventricles and subarachnoid space are close together, combined filling may accurately indicate the size of a neoplasm.

**Procedure:** If filling of the general subarachnoid space as well as of the ventricles is desired, interchange of fluid and gas is continued with the head erect after the ventricles have been filled.

Gas rises to the highest area; for example, the head is dorsiflexed if it is desired to fill the frontal subarachnoid space, and flexed if the ambient cisterns and occipital region is to be filled.

Occasionally (as with a small suprasellar tumour) it may be desirable to insufflate only the subarachnoid space, and this may be done by dorsiflexing the head strongly from the start (Fig. 3d).

Stereoscopic films are useful in studying the subarachnoid space and it is desirable to have the area under examination near the film.

**Value of subarachnoid filling:** Subarachnoid filling is useful in only a small proportion of investigations. The small volume which may enter while the ventricles are being filled is usually all that is necessary—or varying additional amounts may be introduced. The avoidance of subarachnoid filling greatly diminishes discomfort during and after the investigation; hence an understanding of its value is desirable:

1.—The complete diagnosis of cerebral atrophy, generalized or localized.
2.—In conditions causing obliteration or distortion of the subarachnoid space.
   (a) Neoplasms in the lateral recesses. (b) Neoplasms in the suprasellar region. (c) Meningiomas or large aneurysms over the surface of the brain. (d) Foraminal and incisural herniation. (e) In cases of neoplasm when the ventricles fail to fill, subarachnoid filling may give an indication of localization. However, this rarely suffices for surgical attack except in (a), (b) and sometimes (c). (f) Hydrocephalus. (g) Arachnoiditis. Subsequent reference will be made to many of these points, but some are beyond the purpose of this communication. (h) To test the permeability of the arachnoid membrane in patients suffering from post-traumatic symptoms. (i) Occasionally cervical myelography as well as encephalography may be usefully included in the one diagnostic procedure. The cervical canal is filled after the cranium is replete and lateral and axial films are taken in the erect posture. In children it is occasionally desirable to fill the
whole spine as well as the cranium, as when the differentiation of a cerebral or spinal cause of paraplegia is dubious on clinical grounds. Filling of the spine may be accomplished in recumbency with a slight elevation of the shoulders; and, after taking films of the spine, the head and trunk are elevated to fill the ventricles.

**SUPRASELLAR FILLING**

Space-occupying lesions in the suprasellar region are ideal for pneumoencephalographic delineation since there is little normal solid tissue to conceal the mass and subarachnoid space usually caps the tumour. Further, the intracranial pressure is usually normal, for visual loss brings the patient under observation before the third ventricle is blocked.

**Technique**

1.—About 15 c. cm of gas is slowly introduced into the ventricles with the head well flexed (Fig. 10a).

![Fig. 10](image)

*Fig. 10. Postures for showing the suprasellar region:*
  (a) the head and neck is flexed to introduce gas into the ventricles.
  (b) the head is fully dorsiflexed to picture the antero-inferior portion of the third ventricle.
  (c) the head is next mildly dorsiflexed to fill the interpeduncular and chiasmatic cisterns.

2.—The head is then dorsiflexed as fully as possible (Fig. 10b) and a lateral film taken. This shows the anterior horns and the anterior part of the third ventricle. If a tumour be present, the anterior-inferior part of the third ventricle is raised and indented in crescentic fashion (Fig. 11).

3.—This procedure may be repeated after introducing a further 5 c. cm of gas.

4.—Further gas is now introduced with the head dorsiflexed in order to fill the interpeduncular and chiasmatic cisterns (Figs. 10c and 12). Lateral and axial films are taken, the latter with the central ray directed along the floor of the anterior fossa.

The information may be amplified by (a) a lateral film taken with the recumbent patient's brow uppermost. (b) an antero-posterior film in the same posture, to show any encroachment upon the anterior horns. (c) if lateral spread is suspected, the temporal horns may be filled and an antero-posterior film taken. (d) axial and lateral tomograms passing through the sella.
Interpretation: The initial films are designed to show the indentation of the third ventricle by the apex of the tumour before the clarity of the shadow is obscured by subarachnoid gas. The tumour is usually capped on each side

Fig. 11. To show the crescentic deformity of the third ventricle produced by a large craniopharyngioma.

Fig. 12. To show the filling defects produced in third ventricle and suprasellar cisterns by a large chromophobe adenoma. Note that the dense lower shadow does not indicate the size of the tumour.
by the raised subarachnoid space of the basal cisterns, and it is important not to be misled by the lowest and most obvious shadow. The full size of the tumour is usually indicated by a less obvious curvilinear shadow at a higher level. Axial views may show the tumour to be asymmetrical.

**POSTERIOR CRANIAL FOSSA**

It is easier, when no block exists, to picture the 4th ventricle while gas is passing through it from below, than from gas first introduced into the lateral ventricles. Further ventricular and subarachnoid filling may provide complimentary information. It is unfortunate that the presence of a tumour, especially when the pressure is raised, may prevent filling.

*Technique:* The head is strongly flexed with the chin tucked into the neck, until the eye-ear line slopes 50° to 60° below the horizontal.

Forty c.cm. of cerebrospinal fluid is then replaced by gas, and the following films are taken:

1. An axial film, with the central ray passing through the foramen magnum.
2. A second axial film, with the eye-ear line sloping about 30°, and center-

![Diagram of the posterior cranial fossa](image)

*Fig. 13. To illustrate the radiography of the posterior cranial fossa.*

Three axial views are taken with the ear-eye line horizontal and inclined downwards 20°, and 50°. The radiographic appearances at these postures are reconstructed from a lateral view.

*Key:* Horizontal hatching, third ventricle; vertical hatching, aqueduct and fourth ventricle; stipple, cisterns; dotted line, foramen magnum; a, ambient cistern; b, cisterna venae magna cerebri; c, medulla; d, medullary cistern; e, vallecula; f, lateral recesses of pontine cisterns; g, internal auditory canals.
Fig. 14. A very large acoustic neurinoma obliterates the right lateral recess, displaces the medulla to the left, and causes marked displacement and distortion of the fourth ventricle. In the tracing, the third ventricle is represented by horizontal hatching; the aqueduct, fourth ventricle and vallecula by vertical hatching; cisterns, stipple; foramen magnum, dotted line, as in figure 13.

Fig. 15. An acoustic neurinoma, faintly outlined by gas over its convexity, obliterates the right lateral recess and slightly displaces the fourth ventricle. Key to tracing as in Fig. 13 and 14.

ing higher.

3.—A third axial film with the eye-ear line horizontal or sloping 10° downwards. The centering is now on the 4th ventricle.
4.—A lateral film, centering upon the 4th ventricle.

If amplification is necessary, the series may be repeated after a further 40 c.cm has been introduced, and perhaps after complete replacement.

Tomography in the vertical plane, autotomography (slowly rotating the head from side to side during a long exposure), inclination of the head to one side, and tomography in recumbency may be used when the 4th ventricle is concealed by dense petrous temporal shadows or extensive aeration of the temporal bones.

*Interpretation:* The reading of these films requires a detailed knowledge of radiological anatomy (Figs. 13, 14 & 15). A close study of the lateral recesses is often repaid, for pneumoencephalography is very useful when the clinical picture of tumours in this region is unusual. The lateral recess is obliterated. A crescentic filling defect in the remaining shadow is quite frequent and occasionally the upper surface of the tumour is outlined by a thin layer of gas.

**INCREASED INTRACRANIAL PRESSURE**

When the intracranial pressure is raised, it is often impossible to demonstrate the causal lesion by pneumoencephalography, since no gas reaches the affected region. Thus the writer prefers some other method of investigation (angiography, ventriculography or opaque ventriculography, depending on the type of lesion). However, pneumoencephalography is sometimes desirable, as when other measures have failed to give sufficient information. In these instances the danger of herniation through the foramen magnum and the incisura tentorii must be minimized.

*Preliminary measures:* A course of oral urea serves to lessen the intracranial pressure.

Premedication is reduced to a minimum or avoided. Sodium phenobarbital (combined with a barbiturate antagonist) may be used.

Co-ordination with the neurosurgeon is established.

Pulse and blood pressure records are taken.

*Method:* A single needle of small bore is used, and a clean puncture of dura and arachnoid made, with the sharp, short bevel of the needle directed vertically. These measures reduce the possibility of lowering of pressure by subsequent escape of cerebrospinal fluid, such as is responsible for post-lumbar puncture headache.

The stilette of the needle is removed without allowing escape of cerebrospinal fluid, and 7 c.cm. of gas is slowly injected. A lateral film is then taken, centering upon the foramen magnum. Failure of filling the fourth ventricle is an indication for caution. A small additional amount of gas is injected and lateral and axial films taken. If it is obvious that no other information will be gained, it is better to stop the investigation, for foraminal herniation exists. Failure of gas to rise
above the aqueduct and the ambient cistern, indicates the presence of incisural herniation and again nothing is to be gained by continuing (Fig. 16).

If gas passes distally, more may be injected and further films taken until the maximum of information is obtained. If no block exists, it is probably safe to evacuate fluid while gas is injected in order to avoid increasing the pressure, which might lead to venous stasis and cerebral oedema.

Sometimes the lateral ventricle cannot be filled on the side of a cerebral tumour, due, perhaps, to a lessening of the capacity of the ventricle to expand to receive gas.

When the ventricles fail to fill, careful study of the subarachnoid space may give some indication of the position of the neoplasm.

**HYDROCEPHALUS**

The need for special techniques depends upon the desirability of obtaining the maximal information with the minimal volume of gas. Maximal ventricular filling involves danger, possibly from displacements leading to ischaemia, or from the slow absorption of such a large volume of gas.

*Technique:* About 7 c.cm. of gas is introduced with the head flexed (ear-eye line about 30° downwards), and lateral and axial films are taken. Subsequently the method used is modified according to the findings:

1. The fourth ventricle is small and in the median plane. Only the lower part of the aqueduct fills, and the termination of the shadow is usually pointed (Figure 17). This film may provide all the information that is to be gained, but another 10-15 c.cm. may be injected to insure that the finding is not artefact. The head is then brought into the erect posture for further radiography. At this stage subarachnoid gas will show the callosal and cingulate sulci to be bowed upwards and other sulci are usually narrow.

2. Blockage of the foraminae of Magendie and Luschka.

No gas enters the fourth ventricle. This is confirmed by another injection. If the foraminae alone are blocked, the cisterna magna may fill and even be large. However, adhesions may obliterate the whole cistern, or gas may pass anterior to the medulla.
3.—Blockage of the subarachnoid space.

The initial film shows gas loculated in the dorsal part of a large fourth ventricle.

The head is then brought into the erect posture and a small volume of gas introduced. This gas passes into the dilated lateral ventricles and their size may be clearly shown by taking films with the brow, vertex and occiput up.

Next, the head is dorsiflexed and gas injected to determine the level of the block in the subarachnoid space. This is usually at the level of the tentorium, but it may be over the hemispheres.

4.—"Otitic hydrocephalus"—thrombosis of sagittal or lateral sinuses.

The ventricles fill and are only slightly enlarged.

The head is placed in the erect posture in order to fill both ventricles and subarachnoid space. The greatest dilatation is found to be of the subarachnoid space at the vertex.

**Pneumoencephalography in Childhood**

The proceeding may be regarded as safe whatever the age of the child, although the risk of anaesthesia is added. The youngest subject in the writer's experience was three weeks.

Inhalational anaesthesia, delivered through an armoured intratracheal tube of suitable diameter, is best and safest for maintaining anaesthesia. Cyanosis must be avoided.

A smaller chair and small needles are used. It is best to have a variety of sizes. The chair is slipped under the recumbent patient before adjusting the
straps, and then the chair is slowly brought up into the vertical. Fixing the shoulders to the back of the chair by adhesive strapping promotes stability and is especially useful in a small child with hydrocephalus.

The uses of pneumoencephalography in infants and children: The lavish use of pneumoencephalography in childhood is to be deprecated, otherwise a very high proportion of investigations which do not help the patient will be done. The percentage of abnormalities found will, of course, be higher. Appearances suggesting cerebral hypoplasia are frequent, but these do not necessarily indicate abnormality. It is difficult to establish a normal in children; and this applies particularly to the width of the sulci and the subarachnoid space. Widening, so gross as to suggest atrophy in an infant, may be replaced by a normal appearance in a later pneumoencephalogram. Dehydration in infants may lead to shrinkage of the brain.

The indications may be summarized:

1.—The investigation of the position of the block in hydrocephalus.

2.—The investigation of the suprasellar region. The early recognition of a craniopharyngioma or a glioma of the optic nerve may allow of complete extirpation which would be impossible later.

3.—To distinguish gliomatosis of the pons from other neoplasms in the posterior fossa, and thereby eliminating the need for surgery.

4.—The diagnosis of space-occupying lesions within the cerebral hemispheres. In children, neoplasms above the tentorium are relatively rare.

5.—The investigation of selected cases of epilepsy, usually those with focal evidence. Even in these, no lesion is usually found, while atrophy is the commonest deduction. Occasionally a degenerative cyst amenable to surgery is found, and, very rarely indeed, neoplasm.

6.—The recognition of subdural collections in certain cases, when the diagnosis is uncertain and the collection is situated in unusual sites. (Pneumoencephalography usually follows a failure of exploration to detect the lesion).

7.—Occasionally the information of developmental lesions assists in the conduct of the case.

CAUSES OF FAILURE AND THEIR CORRECTION

An unvarying technique produces a fair proportion of failures. The following causes may be recognized in the initial film, and steps taken for securing filling:

Pathological causes.

Recognition may be life-saving. The presence of an organic block is almost certain if the fourth ventricle fails to fill in response to the technique described.

Anatomical causes.
Variations in the cisterna magna are responsible for most failures.

1.—Large cisterna magna.

**Appearances in initial films:** The cisternal shadow is larger than usual, extending upwards to the inion (Fig. 18). A large area of the occipital bone is covered by the cistern, which may contain as much as 80 c.cm. of gas. Although gas loculates here, this is not a bar to filling.

![Fig. 18. Tracing of initial axial and lateral films showing the shadow of a high but narrow cisterna magna.](image)

**Correction:** Gas is injected until the fluid-gas level in the cistern is brought down to the “sill” provided by the vermis. Gas then flows forwards into the vallecula and fourth ventricle. The use of a large volume of gas may be avoided by dorsi-flexing the head to bring the posterior part of the cistern below the level of the vermis. The gas is thus, as it were, decanted into the fourth ventricle. Transferring the patient to recumbency also produces inflow.

2.—Wide cisterna magna.

**Appearance:** Gas passes around the cerebellar hemispheres to the cerebello-pontine angles, and thence upwards to the ambient cisterns, (Fig. 19), a pathway which, under these conditions, is higher than the vallecula (Fig. 20).

![Fig. 19. Tracing of early shadows of subarachnoid filling without ventricular filling. The interpeduncular and ambient cisterns lead to the cisterna venae magna cerebri.](image)

**Correction:** Introduce gas with the head erect in the hope that some will rise directly into the vallecula (Fig. 3 b & c). If none enters the ventricles, proceed to complete replacement when some ventricular filling may occur.
3.—Cisterna magna unloculated above.

Appearance: Gas rises over the vermis to the cisterna venae magnae cerebri, and no gas is seen in the pontine, interpeduncular and ambient cisterns, which provide the usual route to the cisterna venae magnae cerebri (Figs. 21 & 22).

Correction: As in 2 (Fig. 23).

Technical errors
Injection of gas into the subdural space is common, while injection into the epidural space is rare.

1.—Subdural insufflation.

Appearance: Initially gas is seen in a narrow column in the region of the

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Fig. 21. Film showing flow of gas around the vermis of the cerebellum.
foramen magnum. Next it is seen at a higher level behind the incisura tentorii. The postero-anterior shadow has two lateral wings (Fig. 24). As more gas is introduced, the wings spread laterally and posteriorly until the inferior surface of the tentorium is clearly outlined. Thence gas rises alongside the falx to the subdural space at the vertex, which widens to accommodate the gas.

Anteriorly subdural gas may rise in a narrow column behind the dorsum

Fig. 22. Tracing of lateral and axial films. In the absence of loculation of the cisterna magna, the gas level does not sink to the level of the vallecula.

Fig. 23. With the head erect, some gas may rise directly into the vallecula.

Fig. 24. Tracing of early shadows of subdural gas.
sellae and then turns to cross the mouth of the sella to the floor of the anterior fossa.

These shadows are dark, with well defined edges, until the gas spreads in shelving manner over the hemispheres.

Comment: The gas usually gains the spinal subdural space at the point of the needle. Fluid is evacuated coincidentally because fluid has gained the subdural space, or because the arachnoid flaps about the bevel, some gas then also passing into the ventricles. The initial sighting of subdural gas in films taken 24 hours after encephalography would seem to be against this assertion; but, if temporal horn views be taken immediately after injection, large accumulations of subdural gas are seen alongside the falx. (In the usual films the gas is spread over a wide area, and only a thin layer is traversed by the x-ray, while in temporal horn views, a deep thin layer of gas along the direction of the central rays casts a dense shadow.)

In some traumatic cases gas does accumulate in the subdural space within the first twenty-four hours after pneumoencephalography, but discussion of this point is beyond the scope of this paper. It may be said, however, that this is due to altered permeability of the arachnoid, and does not necessarily indicate the presence of a subdural hygroma (a point to be dealt with in a future communication).

Correction: (a) If two needles are in situ, inject through the other needle. (b) Move the needle in, or out, although this rarely rectifies the fault. (c) If gas coincidently passes into the ventricles, continue the replacement. (d) If not, carefully puncture in a higher space. (e) Cisternal puncture will overcome the difficulty, but this puncture should not be attempted by the unskilled. (In the erect posture fluid does not usually flow from the needle.) (f) Postpone the investigation for seven to ten days.

Prophylaxis:—To avoid the embarrassment of a failed investigation: (a) Use fine, sharp needles with short bevels, keeping the plane to the bevel vertical during introduction. (b) Appreciate the piercing of the dura and the arachnoid. (c) Ask the patient to avoid movement of his back. (d) Most important of all, do not perform pneumoencephalography during a phase of post-lumbar puncture headache. The subdural space then contains fluid even before the needle is introduced, while the subarachnoid space is not distended with fluid. Thus the arachnoid is not tense, and is difficult to pierce.

2.—Epidural filling.

Appearances: A rare but perplexing experience may occur when pneumoencephalography is done in a state of post-lumbar puncture headache. Firstly, it is difficult to obtain fluid, and its pressure is extremely low. Nor does the
pressure rise however quickly gas is injected. No gas is seen in the spinal theca, but may be seen in films of lumbar, thoracic and cervical regions ascending along tissue planes outside the spinal column.

Comment: This is due to an accumulation of fluid outside the dura, due to unsealed holes in arachnoid and dura as the result of the previous puncture. The absence of resistance opposed by the membranes makes their puncture unpractical. Fluid under very low pressure may be evacuated from the epidural space, into which gas is injected.

Correction is impossible except by cisternal puncture. It is best to postpone the investigation until the arachnoid and dura have sealed.

Concluding Remarks

Thus, there is no routine pneumoencephalography.

The question is often asked—how much gas is injected? The answer is, the amount which adequately demonstrates the structures or region under investigation. There is no standard volume: it varies with the requirements of the investigation.

Each investigation is an adventure in itself, planned to obtain the maximum of information of a region indicated by clinical assessment. Interest and information will repay care, while the patient gains in comfort and from the accuracy of the information obtained.