

VENTRICULOGRAPHY FOLLOWING THE INJECTION OF AIR INTO THE CEREBRAL VENTRICLES

BY WALTER E. DANDY, M.D.

OF BALTIMORE, MD.

(From the Department of Surgery, the Johns Hopkins Hospital and University)

THE value of röntgenography in the diagnosis and localization of intracranial tumors is mainly restricted to the cases in which the neoplasm has affected the skull. In an analysis of the X-ray findings in one hundred cases of brain tumor from Doctor Halsted's Clinic, Heuer and I¹ have shown that in only 6 per cent. of the cases did the tumor cast a shadow, and in these it was only the calcified areas that were differentiated by the X-rays from the normal cerebral tissues.

In those instances (9 per cent. of our cases) in which a tumor has encroached upon the sphenoid, ethmoid or frontal sinus, the invading portion casts a shadow in the röntgenogram. Such shadows are due to the displacement of the normally contained air by tissues which are less pervious to the X-ray. This group of shadows is of minor practical importance because the growth can be recognized by the destruction of the walls or bony septa of the sinuses.

Since the X-rays penetrate normal brain tissues, blood, cerebrospinal fluid and non-calcified tumor tissue almost equally, any changes in the brain produced by altered proportions of these components will not materially alter the röntgenogram.

Although skull changes are shown by the X-ray in 45 per cent. of our cases and are frequently pathognomonic, on the whole they represent late stages of the disease. As intracranial tumors come to be diagnosed and localized earlier, the value of the X-ray will be correspondingly diminished.

For some time I have considered the possibility of filling the cerebral ventricles with a medium that will produce a shadow in the radiogram. If this could be done, an accurate outline of the cerebral ventricles could be photographed with X-rays, and since most neoplasms either directly or indirectly modify the size or shape of the ventricles, we should then possess an early and accurate aid to the localization of intracranial affections. In addition to its radiographic properties, any substance injected into the ventricles must satisfy two very rigid exactions: (1) It must be absolutely non-irritating and non-toxic; and (2) it must be readily absorbed and excreted.

The various solutions and suspensions used in pyelography—thorium,

¹ Röntgenography in the Localization of Brain Tumor, Based Upon a Series of One Hundred Consecutive Cases. The Johns Hopkins Hosp. Bull., 1916, xxvii, 311. Also: A Report of Seventy Cases of Brain Tumor. The Johns Hopkins Hosp. Bull., 1916, xxvii, 224.

potassium, iodide, collargol, argyrol, bismuth subnitrate and subcarbonate, all in various concentrations—were injected into the ventricles of dogs, but always with fatal results, owing to the injurious effects on the brain. Marked cedema, serosanguineous exudate, and petechial hemorrhages resulted. The severe reactions that are sometimes encountered after the intraspinal injection of most therapeutic remedies indicate the dangers even from carefully prepared solutions. A slight acidity or alkalinity may result even in death. It seems unlikely that any solution of radiographic value will be found which is sufficiently harmless to justify its injection into the central nervous system. Suspensions are precluded because they are not absorbed.

Ventriculography, therefore, seems possible only by the substitution of gas for cerebrospinal fluid. It is largely due to the frequent comment by Doctor Halsted on the remarkable power of intestinal gases "to perforate bone" that my attention was drawn to its practical possibilities in the brain. Striking gas shadows are present in all abdominal and thoracic radiograms. The stomach and intestines are often outlined by the contained air, even more sharply than when filled with bismuth. A small collection of gas in the intestines often obliterates the kidney outlines. A perforation of the intestines may be diagnosed by the shadow of the air that has accumulated under the diaphragm. Gas gangrene may be diagnosed by the air blebs (of *B. welchii*) in the tissues. Pneumothorax is sharply outlined because the normal lung tissues are eliminated. The paranasal sinuses and mastoid air cells show up in a thick skull by virtue of the air, and pathological conditions of the sinuses are evident because inflammatory or tumor tissue replaces the air. From these and many other normal and pathological clinical demonstrations of the radiographic properties of air it is but a step to the injection of gas into the cerebral ventricles—pneumoventriculography.

Methods.—Several gases are inert and readily absorbable, and in these respects satisfy the requirements for injection into the cerebrospinal system. Although it is possible other gases give even better results, we have used only air in the injections here described. The merits of other gases are now being studied.

In order to obtain a skiagram of the lateral cerebral ventricles filled with air, it is necessary to remove at least more cerebrospinal fluid than the contents of one ventricle and to replace this fluid with an equal quantity of air. Before closure of the fontanelles, one can readily make a ventricular puncture through the interosseus defect. After union of the sutures, it is necessary to make a small opening in the bone.

Air and water in a ventricle behave exactly as they would in a closed flask. Following any change in position the fluid gravitates to the most dependent part and the air rises to the top. Owing to the free communication between the third, the right and the left lateral ventricles through the foramina of Monro, fluid and air will readily pass from one ventricle to the other. Because of the curves in the ventricular system, however, it is obvious that in any given position, only part of the ventricular fluid can gravitate to the point

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of the needle, so that this amount only can be aspirated. If desired, fluid can be removed from the remaining recesses by tilting the head, just as one manipulates a curved tube to replace the fluid with air. Theoretically, it should be possible to remove nearly all the ventricular fluid by suitable manipulations of the head, but for practical purposes enough fluid can be obtained from one correct position. Visualization of the ventricular system will best indicate the most appropriate location for ventricular puncture and the proper position of the head. It will then be seen that the most fluid can be obtained from a puncture in the anterior part of either lateral ventricle (Fig. 2). The head should be placed with the face down and partially rotated so that the ventricle to be aspirated is beneath and the needle enters at the most dependent point possible. This position permits the maximal drainage of fluid from the opposite lateral and the third ventricles. Aspiration through a puncture in the posterior or descending horn permits a fairly complete removal of the fluid from one ventricle and from that portion of the other lateral ventricle which is anterior to the foramen of Monro. In the aspiration of fluid from the posterior horn of the lateral ventricle, the patient must lie with the face directed upward and backward and the head rotated from 30 to 40 degrees toward the side of the needle.

The exchange of air for cerebrospinal fluid must be made accurately. If the air injected is greater in volume than the fluid withdrawn, acute pressure symptoms will result. To attain accuracy we have used a Record syringe with a two-way valve attachment (Fig. 1). A small amount of fluid (20 c.c.) is aspirated and an equal quantity of air injected. This is repeated until all the fluid has been removed. By aspirating and injecting in small quantities, injury to the brain from negative pressure is prevented. Not knowing the size of the ventricles beforehand, we have no way of estimating the amount of air necessary to fill one ventricle. For this reason we have preferred the removal of all the fluid that can be readily obtained. This has been found to be but little greater than the contents of one ventricle.

Needless to say, owing to the lighter weight of air, the ventriculogram represents the ventricle farthest from the X-ray plate. To insure the best results the sagittal plane of the head should be parallel with the plate. Valuable assistance can also be obtained from anteroposterior X-rays. The head should then be placed so that the sagittal plane is vertical, preferably with the occiput resting on the plate. With the latter precaution a more even distribution of air on the two sides is obtained and the ventriculogram represents the anterior portions of both lateral ventricles. For special points in diagnosis additional anteroposterior views may be taken of the posterior and descending horns of the ventricle by placing the forehead on the plate.

Results Following Injection.—We have injected air into the cerebral ventricles at least twenty times. In some instances the injection has been repeated. The amount of air injected has varied from 40 to 300 c.c., the larger quantities in cases of internal hydrocephalus. Only once has there been any reaction, and in this case the injection (300 c.c.) was made forty-eight hours

after the first stage of an operation for cerebellar tumor (Fig. 3). The reaction was characterized by a rise of temperature, nausea, vomiting, and increased headache, all of which were quickly relieved after release of the air by a ventricular puncture. Ten days later, a large cerebellar tumor was removed, the patient making an uneventful recovery. All of the injections have been made in children varying from six months to twelve years of age. Invariably the lateral ventricle has been sharply outlined in the radiogram. In two instances the third ventricle and the foramen of Monro were visible

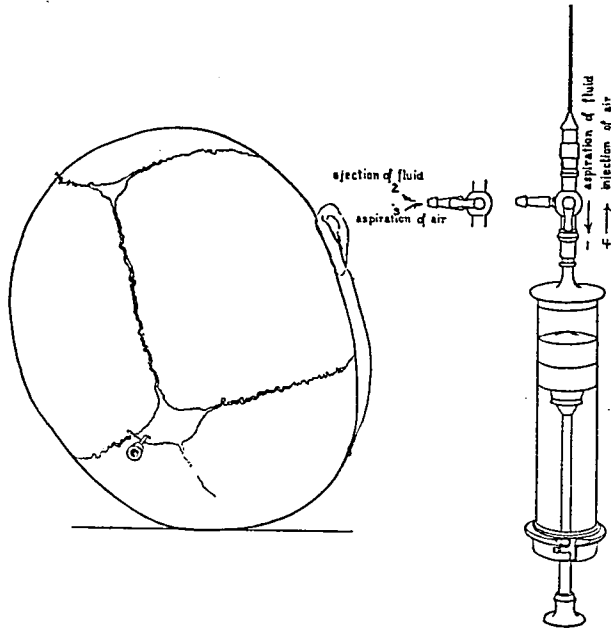


FIG. 1.—Showing oblique position of head for aspiration of fluid and injection of air. The forehead is resting on plate. Note point of entrance of the needle into anterior fontanelle on dependent side. Figure on right shows record syringe and two-way valve attachment used for this purpose.

(Figs. 3 and 8). In none, however, have we observed the fourth ventricle or the aqueduct of Sylvius. The practical value from pneumoventriculography is expected principally from the shadows of the lateral ventricles.

Day by day the air shadow diminishes and eventually disappears. In a case of internal hydrocephalus it required two weeks. Possibly in more normal cases the time may be less, as air in other body tissues vanishes much more rapidly. In all probability absorption of air injected into the ventricles takes place by the same channels as in the case of the ventricular cerebrospinal

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fluid. In a previous communication² it has been shown that cerebrospinal fluid is almost entirely absorbed from the subarachnoid space; that only a very slight absorption takes place from the ventricles. Phenolsulphonephthalein in a closed ventricular system disappears in from ten to twelve days, whereas it is absorbed in from ten to twelve hours when the ventricles communicate with the subarachnoid space, where the absorption of cerebrospinal fluid normally takes place.

Air introduced into the ventricles acts in no way differently from the air included at every intracranial operation. Following tumor extirpation especially, the resulting defect fills with air which, unless displaced by salt solution, is shut in when the dura and scalp are sutured. For a few days pending its absorption from tumor defects the patient may be conscious of the move-

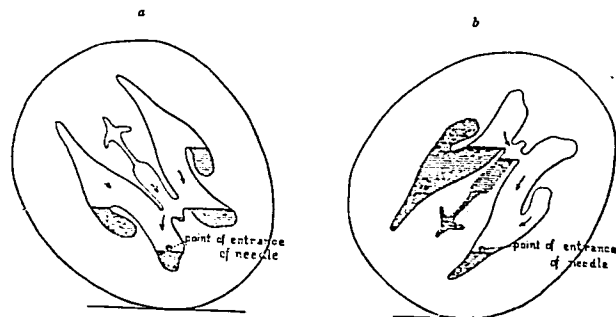


FIG. 2.—Diagrams showing relative amounts of cerebrospinal fluid that can be removed from a single ventricular puncture: (1) when forehead is down (a) and (2) when occiput is down (b). Shaded area represents the fluid which remains in the ventricular system after the greatest possible quantity has been removed. Unshaded area represents maximum quantity of air which can be injected to replace the fluid withdrawn. It is evident that more fluid can be removed when the puncture is made anteriorly and the forehead is dependent.

ment of the air when the head is turned, but its presence is without any other effects.

The Value of Ventriculography.—Even in the few cases here reported ventriculography has proven of great practical value. For the first time we have a means of diagnosing internal hydrocephalus in the early stages. Internal hydrocephalus is one of the most insidious diseases of the brain and is rarely diagnosed before a considerable amount of cortical destruction has resulted. This is true of adults as well as of children. With exact visualization of the ventricles the findings are pathognomonic. Not only the existence of hydrocephalus but its degree and the amount of brain destruction are at once evident from the ventriculogram.

In one case (in an infant six months old) an internal hydrocephalus was suspected from a bulging fontanelle, but the ventriculogram showed

²Dandy and Blackfan: *Am. J. Dis. Child.*, 1914, viii, 406; 1917, xiv, 424. Also *J. Am. M. Assoc.*, 1913, lxi, 2216.

no enlargement of the ventricles. Another child (three years old) remained drowsy for several days after apparent recovery from an attack of epidemic cerebrospinal meningitis. The spinal fluid was clear and contained no organisms. The ventricular fluid was turbid and organisms were present; the ventriculogram demonstrated a greatly enlarged ventricle. The diagnosis of obstructive internal hydrocephalus, clinically unsuspected, was made with absolute certainty from the ventriculogram.

In two other children measurements of the head were normal but hydrocephalus was suspected because of abnormally large fontanelles. In each case the ventriculogram demonstrated ventricles which nearly filled the cranial chamber (Fig. 5).

One of the most interesting diagnoses, made possible only through the ventriculogram, was in a colored child eight months old. The head was definitely larger than normal, indicating the probability of an internal hydrocephalus. Over the anterior fontanelle, but slightly to one side, was a protruding tumor suggesting a meningocele, and this diagnosis had been made. Air injected into the lateral ventricle passed directly into the tumor. In the lateral ventriculogram the tumor was seen to arise from the greatly distended ventricle by a narrow neck (Fig. 6). An anteroposterior ventriculogram showed this communication to be unilateral. The diagnosis of a ruptured cortex with a (false) ventricular hernia was established, and subsequently verified at necropsy.

In another case a large cerebellar tumor was removed from a boy twelve years old. The large head, the marked convolitional atrophy of the skull, blindness, and the location of the tumor, made the diagnosis of internal hydrocephalus certain, but only the ventriculogram gave an accurate estimation of its advanced degree and the amount of brain destruction (Fig. 8).

Without a ventriculogram the diagnosis of internal hydrocephalus in children is frequently guess-work; with the ventriculogram the diagnosis is absolute.

We have as yet not obtained a normal ventriculogram. In one of these cases the ventricle was small but not known to be normal. It is possible that one of the earliest signs of internal hydrocephalus may be alteration in the shape of the ventricle due to the pressure effects on parts of the wall which are least resistant. The obliteration of the angle between body and posterior horn in Fig. 5 (contrasted to Fig. 3) suggests this probability, but ventriculograms of the intervening stages and the normal are lacking.

We have not yet applied ventriculography to adults, but expect to do so in all cases in which the diagnosis is obscure. In a boy of twelve years the ventriculogram was even sharper than in younger children. In adults we should expect the ventriculogram to be at least as sharp or possibly even more so because of the greater contrast between the density of air and bone. Several possibilities are anticipated from ventriculograms in adults: (1) The enlarged ventricles in internal hydrocephalus should be absolutely defined.

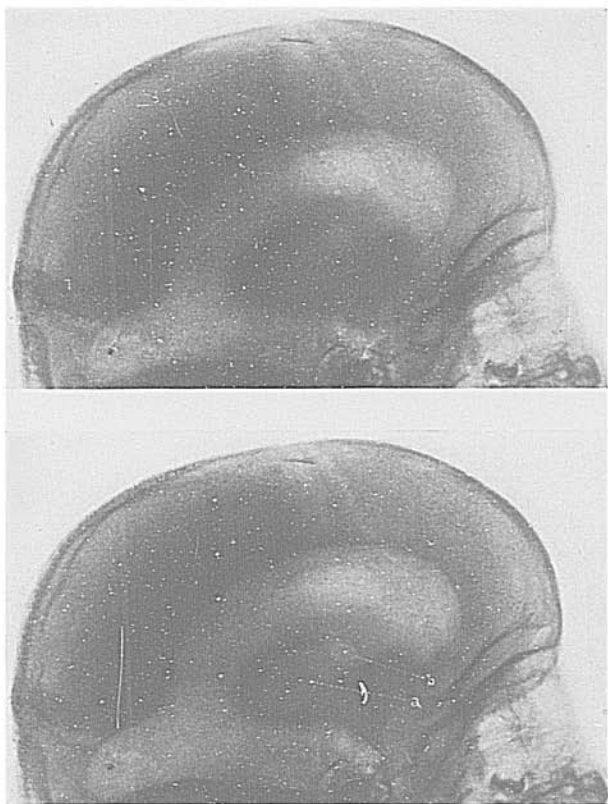


FIG. 3.—Ventriculogram in a child three years old, with tuberculous meningitis. The ventricle is slightly dilated, an early obstructive hydrocephalus having resulted from closure of the foramina of Magendie and Luschka by exudate. The separation of the frontoparietal sutures also indicates intracranial pressure. *a*, third ventricle; *b*, probably the foramen of Monro. The body, the posterior horn, and the descending horn of the lateral ventricle are obvious.

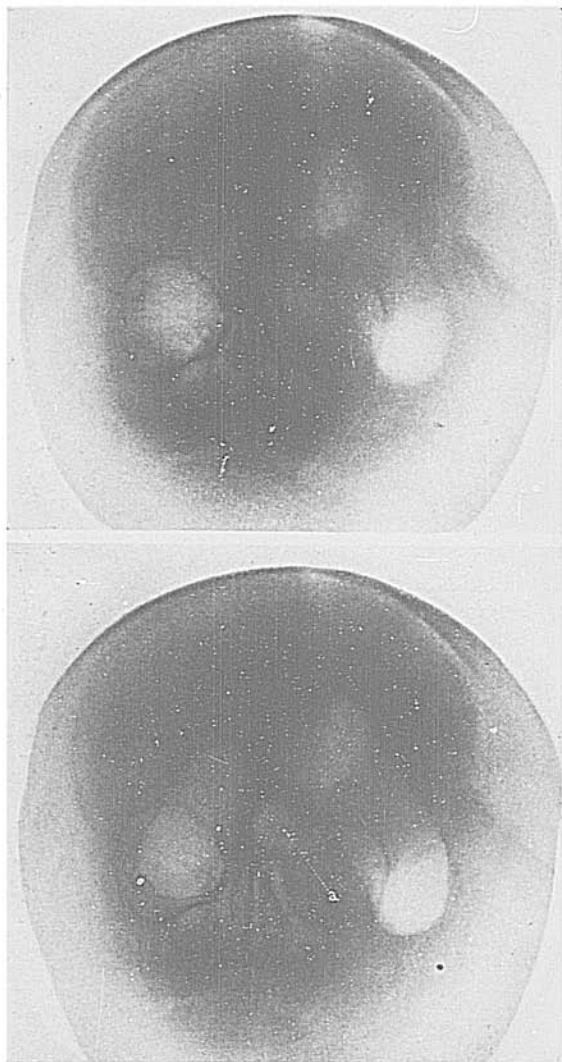


FIG. 4.—Anteroposterior ventriculogram of Fig. 3. Note the unequal distribution of air on the two sides. The ventricle shadow is greatest in the body and descending horns, owing to the depth of the column of air. The posterior curved and ventral part of the ventricle shows as a lighter shadow, communicating the two deeper shadows. The shadow is lighter because the smaller column of air gives relatively less penetration to the Röntgen rays. The curvature of the ventricles and the perspective are brought out by stereoscopic vision. *a*, third ventricle.

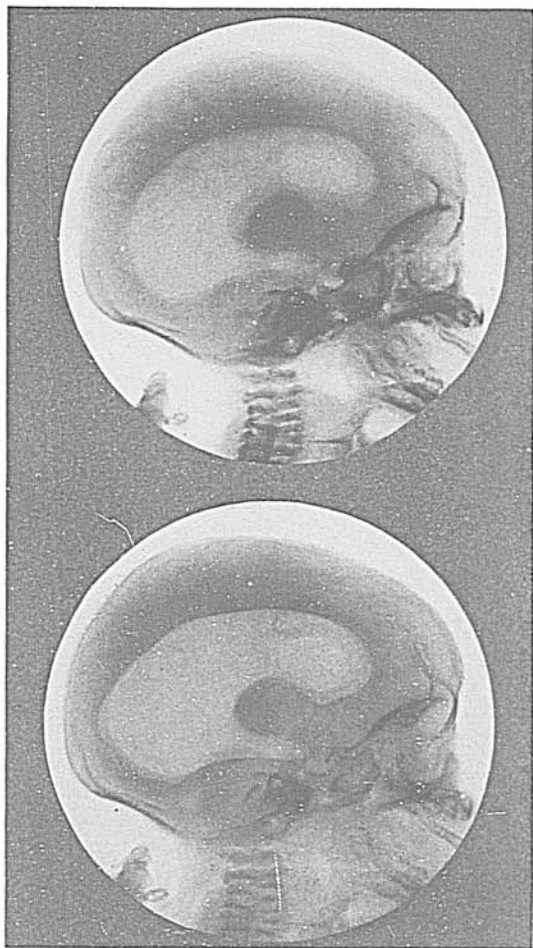


FIG. 5.—Ventriculogram of moderately distended ventricle in a case of communicating hydrocephalus. The size of the head is normal. Note the obliteration of the more normal ventricular contour shown in Fig. 4. The posterior horn is supplanted by a diffuse posterior bulging. The deeper shadow in the anterior part of the ventricle is due to air in the opposite ventricle.

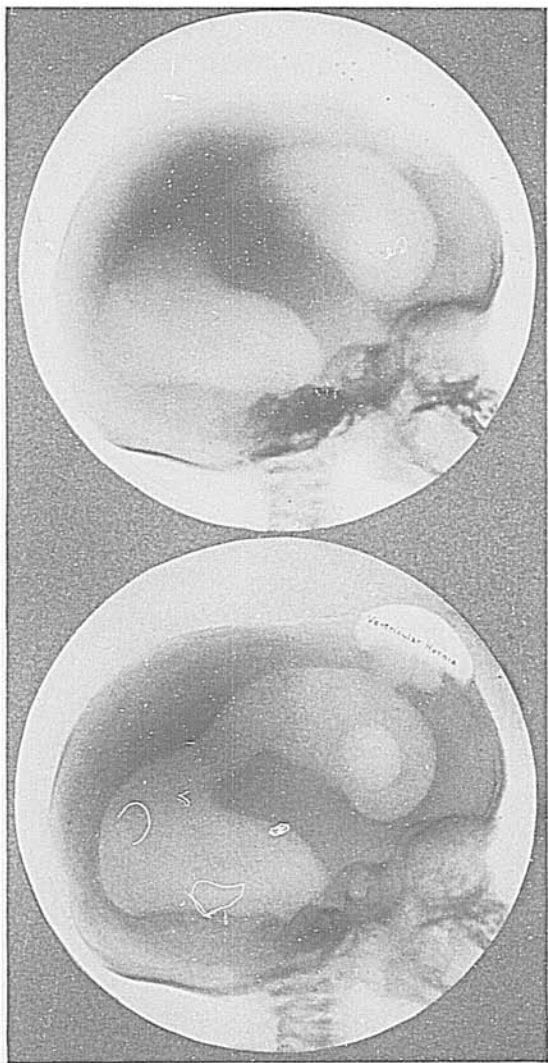


FIG. 6.—Ventriculogram (lateral view) of a more distended ventricle in a fairly advanced case of communicating internal hydrocephalus. Note the ventricular hernia and its neck communicating with the anterosuperior part of the lateral ventricle. It was necessary to draw the hernia in the lower picture because the X-ray shadow of the hernia on the X-ray plate was so slight as to be visible only by an oblique or reflected light. The constriction in the centre of the ventricle is due to the fact that air does not fill the ventricle.

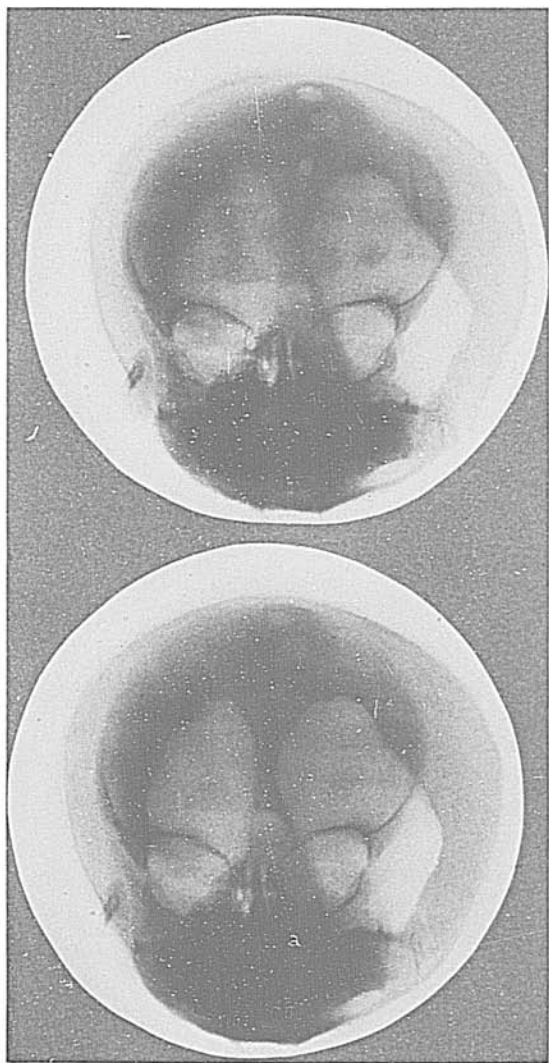


FIG. 7.—Anteroposterior view of Fig. 6. Note the fairly equal distribution of the air in the two ventricles. This is probably due to the more extensive communication due to the enlarged foramina of Monro. *a*, third ventricle.

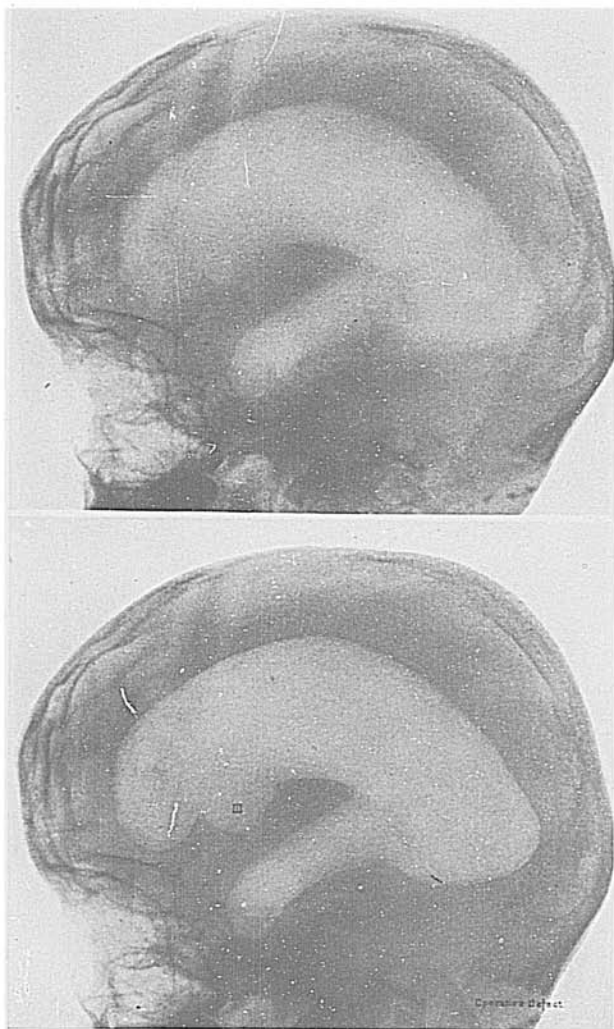


FIG. 8.—Ventriculogram (lateral view) in a large head with closed sutures. The convolutional atrophy of the skull, indicative of internal hydrocephalus, is evident in the occipital and frontal regions. The markings are intensified by the air in the ventricles. III is third ventricle. The downward projection from the third ventricle is probably the infundibulum. The patient was twelve years old. A large cerebellar tumor had been removed.

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- (2) Tumors in either cerebral hemisphere may dislocate or compress the ventricle and in this way localize the neoplasm.
- (3) Tumors growing into the ventricles may show a corresponding defect in the ventricular shadow.
- (4) A unilateral hydrocephalus may be demonstrable if the air cannot be made to enter the opposite ventricle.

CONCLUSIONS

1. The outlines of the lateral cerebral ventricles can be sharply outlined by the X-ray if air is substituted for cerebrospinal fluid.
2. The injection of air into the ventricles has had no deleterious effects in twenty cases.
3. Ventriculography has already proved of great practical value in the diagnosis and localization of many intracranial conditions. It is invaluable in internal hydrocephalus.

NOTE.—*Explanation of Figures.*—Two pictures are shown in each figure number. The upper one is the untouched photographic reproduction of the X-ray plate; the lower is the same photograph retouched by Miss Norris in order to overcome photographic loss of detail, and especially to emphasize the lines and special points which would otherwise be lost to the reader.