THE GROSS ANATOMY OF THE LATERAL VENTRICLES

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INTRODUCTION

Previous papers on the gross anatomy of the cerebral ventricles have been based upon casts and dissection of human brains (Key and Retzius, 1875; Welcker, 1915; Locke and Naffziger, 1924; Locke, 1925). They have been, consequently, subject to several important sources of error such as alteration caused by the fixation of the brain and an injection pressure great enough to cause dilatation of the cavities. Some workers have not obtained a successful cast until they met with a brain with dilated ventricles, and the depicted cast thus presents a moderate but definite case of hydrocephalus.

The author has employed another technique, realising that the anatomy of the ventricles in a living brain is somewhat different from that seen at dissection or as a result of injection. For this purpose casts and dissection of the brain have been correlated with the roentgenological pictures of the ventricles after the cerebrospinal fluid has been exchanged for air. Intraventricular air accidentally introduced had been demonstrated on the X-ray film (Luckett, 1913; Skinner, 1916) before Dandy (1918) introduced ventriculography as a diagnostic method, but it is only since this method has become commonly used that examination of innumerable ventriculograms has given us a detailed knowledge with regard to the cerebral ventricles.

Several variations from the usual anatomical conception have been found and will be described in detail. This is especially true of the posterior part of the lateral ventricle and of the posterior horn in particular.

It has been often questioned whether the foramina of Luschka and Magendie are normal openings present in life or artefacts caused by the manipulations of the brain after death. The introduction of air into the ventricles after it has been injected by lumbar puncture into the spinal canal proves, however, that at least one of these openings must be physiologically present.

TECHNIQUE

Material

For the present purpose eleven brains from adults have been used. The youngest patient was 18 years of age and the oldest 68. All of these patients had died of diseases not connected with the central nervous system, and the brains were fixed in formalin.

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A group of 450 selected sets of ventriculograms and encephalograms has been studied and from this thirteen sets were chosen for the present purpose because they illustrate particularly what we consider, in our experience, to be a normal ventricular system.

Most of these cases were epileptic patients; some of them were cases of post-traumatic headache and some of them suffered from headache of unknown origin. Neoplasms have not been verified in any of the cases. The youngest was 17 and the oldest 48 years of age.

Methods

Two different methods have been employed:

A. One method for the study of the brains and making casts of these.

B. One method for the study of the ventriculograms.

Both methods have been used to decide the same distances and sizes.

Method A

The procedure has been to insert one "brain needle" in the anterior horn, one in the posterior and one in the inferior horn. The needles were of the type commonly used for brain puncture.

The one in the anterior horn was used for injection of melted paraffin (melting point 56° C.), the other two were used as outlets in order to allow the cerebrospinal fluid and air to escape.

The paraffin was injected under pressure of about 1000 mm. of water in order to expel the fluid which was already in the ventricles and in order to hasten the procedure so that the paraffin should not solidify before the entire space had been filled with the substance. This pressure, however, was not great enough to alter the form of the ventricular cavity. Further, the pressure offset the tendency for the paraffin to shrink when solidified.

In order to delay the solidification until the entire space had been filled with paraffin, the rubber tube through which the fluid was running was irrigated constantly with warm water at a temperature between 70 and 80° C., and the brain had been kept in water at 35° C. for 2 hours prior to injection.

When the injection of paraffin had been continued long enough to secure complete expulsion of fluid and air, the surface of the brain and the needles through which the paraffin escaped were irrigated with cold water, causing solidification of the paraffin and preventing further escape of the injected substance. In the meantime the fluid paraffin was kept under the same pressure as before in the needle for injection in order to obtain the best possible filling of the lumina. When the injected mass had solidified in the needle also, the procedure was interrupted and dissection of the brain was undertaken.

During the dissection the distance from the surface of the brain to the ventricle was measured at several points (fig. 10), and the dissection was done in such a manner that the thalamus was left intact in order to give support to the ventricle which was uncovered finally and could be measured.

Findings.

Fig. 1 outlines those parts of the ventricle which have been measured.

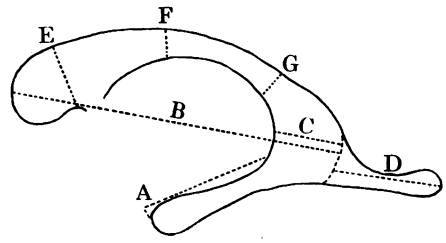


Fig. 1. Sketch showing those distances and portions of the lateral ventricle which have been measured.

As the posterior horn is not a constant part of the ventricles, the distance indicated by *B* in fig. 1 was measured in each case whether or not a posterior horn was present. *B* represents the distance from the anterior horn to the furthermost part of the ventricle regardless of the posterior horn. This manner of measuring the total length of the lateral ventricles is not quite exact, but it is the only way by which comparison can be made.

The following measurements were found:

Left ventricle

(All measurements shown are centimetres.)

	A	*B*	*C*	*D*	*E*	*F*	*G*
Brain 1	3·0	7·5	2·0	1·2	2·0	0·5	0·7
Brain 2	5·0	7·9	2·1	0·8	2·1	1·0	0·8
Brain 3	3·8	7·5	1·9	0·0	1·9	1·0	0·9
Brain 4	4·0	7·9	2·1	0·3	1·6	0·6	0·8
Brain 5	5·0	8·0	1·8	2·0	1·6	0·6	0·6
Brain 6	3·9	8·0	2·0	3·4	1·9	0·5	0·5
Brain 7	4·0	8·1	2·1	0·0	1·7	0·6	0·7
Brain 8	4·0	7·9	1·9	3·6	2·1	0·5	0·5
Brain 9	4·2	7·8	2·0	0·7	1·8	0·7	0·5
Brain 10	4·0	7·9	1·8	0·3	2·0	0·5	0·7
Brain 11	4·0	8·0	2·0	3·0	2·0	0·6	0·7
Average	4·08	7·85	1·97	1·39	1·88	0·64	0·69

Right ventricle

	A	*B*	*C*	*D*	*E*	*F*	*G*
Brain 1	2·5	7·5	1·5	1·3	1·8	0·5	0·7
Brain 2	4·8	8·0	2·0	0·8	2·1	1·0	0·9
Brain 3	3·0	8·0	2·0	0·0	2·0	1·2	1·0
Brain 4	4·3	8·0	1·9	0·4	1·7	0·6	0·8
Brain 5	5·0	7·9	1·8	2·0	1·5	0·5	0·6
Brain 6	3·8	7·9	2·1	3·3	1·9	0·5	0·6
Brain 7	4·1	8·1	2·1	0·0	1·7	0·6	0·6
Brain 8	4·2	7·8	1·9	3·6	2·1	0·5	0·6
Brain 9	4·1	7·8	2·1	0·8	1·8	0·7	0·5
Brain 10	3·9	8·0	1·9	0·4	2·0	0·6	0·6
Brain 11	4·0	8·0	1·8	3·4	1·8	0·6	0·6
Average	3·97	7·90	1·91	1·45	1·94	0·66	0·67

These measurements employed give the results shown in fig. 2.

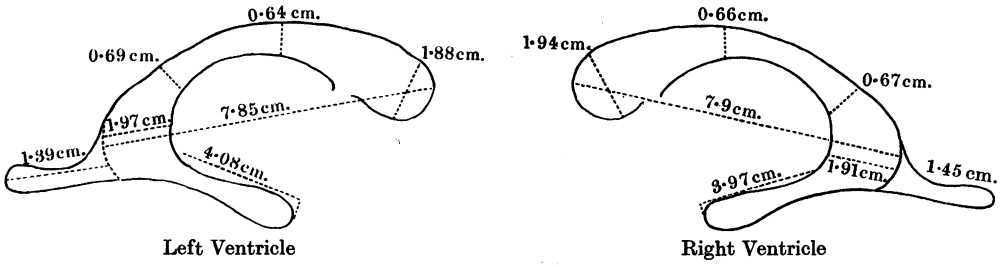


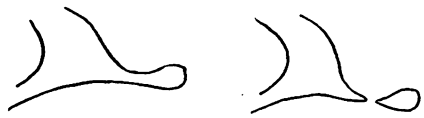
Fig. 2. Sketch showing the findings of the left and right ventricle.

Discussion of the findings. By looking at the two tables one will see that the two parts of the lateral ventricle which show the greatest variation are the posterior and inferior horns.

As already mentioned the posterior horn is not constantly present. In two of the eleven cases the posterior horn was entirely absent. On the other hand, a posterior horn as long as 3·6 cm. was found and in both cases the ventricles had to be considered normal.

It is important to note that in some cases where the calcarine fissure was a rather deep one it seemed to cut in far enough to obliterate the posterior horn.

In other cases there was constriction of the middle part of the posterior horn so that the posterior portion was considerably wider than the middle portion (see fig. 3), and in one of these cases the horn was completely constricted with a cavity posterior to the obstruction (fig. 4).



Figs. 3 and 4. Variations of the posterior horn.

That part of the ventricle other than the posterior horn which showed the greatest variation was the inferior horn. The shortest inferior horn that was found measured 2·5 cm. and the longest 5 cm.

Because it is difficult to determine the border between the posterior horn, the inferior horn and the body of the ventricle, these findings are of approximate value only.

The anterior horn varied in height from 1·6 to 2·1 cm., and the middle and posterior part of the body varied from 0·5 to 1·2 cm. and 0·5 to 1 cm. respectively.

The posterior portion of the body of the lateral ventricle was found to have a rather variable shape (see fig. 5 A, B and C). The difference in appearance of this portion of the ventricle depends upon the splenium of the corpus callosum

which forms the posterior wall at this point. As the illustrations show, the body of the ventricle may at this point run smoothly into the posterior horn, but it may also occur with the formation of an angle, and the incisura at times shows a double formation. All three features are to be considered normal.

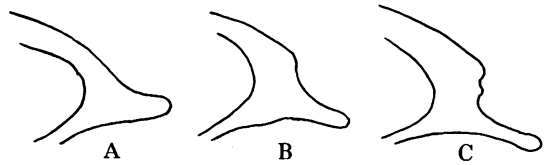


Fig. 5. Variations of the posterior portion of the lateral ventricle.

The length of the lateral ventricle was fairly consistent with a variation from 7·5 to 8·1 cm.

Thus it can be seen that the size of the normal lateral ventricle is not constant as it shows considerable variation, especially of the inferior and posterior horns.

Method for making a lead cast from the paraffin cast.

After the paraffin cast had been dissected free from the brain it was put in plaster of Paris, having been furnished with four columns of paraffin which should serve as vents for the escape of air while the casting is being done. Fig. 6 shows the position of the vents.

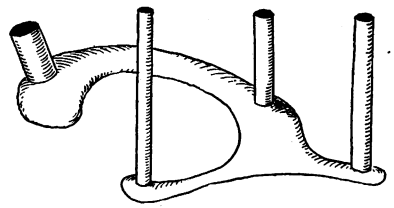


Fig. 6. The ventricular cast furnished with vents ready for casting in plaster of Paris.

The ventricular cast with the columns was then placed in plaster of Paris and after this had solidified it was heated sufficiently to melt away the paraffin. Then the empty cavity was filled with lead, the plaster broken away and finally the lead columns in the vents were removed.

In order to obtain a brass model the lead ventricles can be cast in sand.

Method B

Study of ventriculograms and encephalograms.

When an encephalogram or ventriculogram has been successfully performed one can measure the picture of the ventricle on the X-ray film and, by taking into consideration the extent of the magnification, one can find the

actual size of the ventricle. This can be done by mathematical methods. The following tables show the results of thirteen examinations, and from fig. 7 one can see which distances have been measured. The sizes are indicated in centimetres.

Left ventricle

	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*
	4·0	1·0	0·5	7·9	1·0	1·4	1·8	1·5	1·1
	3·6	0·6	1·0	8·5	1·5	1·3	1·4	1·3	1·3
	3·5	0·5	0·5	8·5	2·0	0·0	1·0	1·5	1·3
	3·0	0·8	0·6	8·5	1·1	1·0	1·6	1·5	1·0
	4·2	0·4	1·1	8·5	1·5	0·0	1·0	1·2	1·3
	5·0	0·7	0·8	8·6	1·0	0·0	1·5	0·8	1·0
	3·5	0·5	0·5	8·6	1·3	1·5	1·5	1·3	1·1
	3·9	1·0	0·8	8·1	1·2	2·0	1·4	1·0	0·8
	3·0	0·7	0·7	8·5	1·5	3·0	2·0	1·6	1·0
	2·5	0·8	0·9	9·5	1·3	0·8	2·0	1·3	0·9
	3·2	0·7	0·7	9·0	1·7	0·0	1·5	1·5	0·8
	4·0	0·4	1·0	10·0	2·0	0·0	2·0	1·5	1·0
	3·5	0·5	1·0	9·0	1·6	2·0	1·5	1·0	0·8
	46·6	8·6	10·1	113·2	18·7	13·0	20·0	17·0	13·4
Average*	3·6	0·7	0·8	8·7	1·4	1·0	1·5	1·3	1·0
Average†	3·28	0·64	0·72	7·76	1·28	0·90	1·36	1·18	0·90

Right ventricle

	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*
	3·5	1·0	0·7	8·0	1·1	1·0	1·0	1·4	1·0
	2·5	0·5	0·5	8·2	1·1	1·3	1·8	1·1	1·1
	4·0	0·5	0·5	10·5	1·5	1·5	1·9	1·0	1·0
	3·3	0·5	0·4	8·0	1·5	2·0	1·7	1·6	1·0
	4·6	1·0	0·6	9·0	1·5	2·5	1·6	1·4	1·5
	5·0	0·7	0·6	8·8	1·4	0·0	1·5	0·8	1·0
	4·4	0·4	0·4	9·0	1·3	1·0	1·5	1·0	1·1
	5·6	1·0	0·6	8·7	1·2	2·0	1·2	0·7	0·9
	2·5	0·7	0·7	8·5	1·5	2·0	1·3	1·3	1·0
	2·6	0·7	0·7	9·0	1·5	1·3	2·0	1·0	1·0
	3·2	0·7	0·7	9·5	2·0	0·0	1·5	1·3	1·3
	4·0	0·5	0·5	10·0	2·0	0·0	1·7	1·5	1·0
	3·5	0·5	1·0	9·7	1·5	2·5	1·5	1·0	1·0
	48·7	8·7	7·9	116·9	18·7	17·1	20·1	15·1	13·9
Average*	3·7	0·7	0·6	8·9	1·5	1·3	1·5	1·2	1·1
Average†	3·38	0·64	0·55	8·1	1·28	1·18	1·36	1·09	1·0

* Average of above nos.

† Average of above nos. taking magnification into consideration.

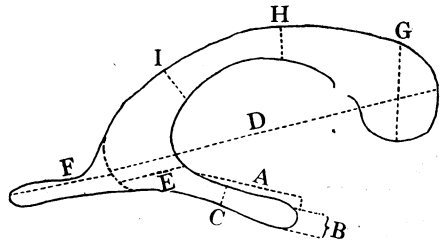


Fig. 7. Sketch showing the distances and portions of the lateral ventricles which have been measured on the X-ray film.

Discussion of the findings. The study of the ventriculograms showed, as has been pointed out previously, that the form and size of the lateral ventricles even under normal circumstances are not constant.

Examination of ventriculograms and encephalograms has taught us that considerable experience is necessary to pass judgment on variations from the normal ventricular form.

First of all it should be remembered that a gradual enlargement of the ventricles takes place during life because of general cerebral atrophy. In other words, if a person 15 years of age presents cerebral ventricles of the size which is normal at the age of 60, these ventricles should be considered abnormally large.

Then it is also our experience that the size and shape of the ventricles normally vary within certain limits in different individuals of the same age. This observation corresponds well with the findings by making casts of the ventricles and with the results of dissection. A ventricular shadow on the X-ray plate is anatomically reliable only when the portion of the ventricle in

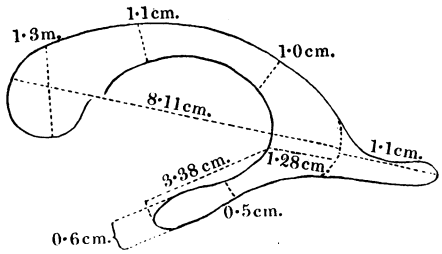


Fig. 8. Illustration of the findings concerning the right lateral ventricle.

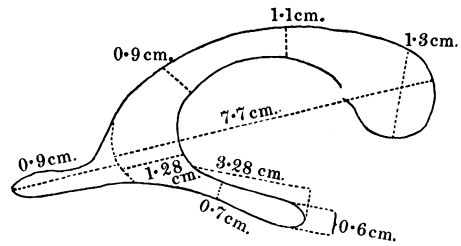


Fig. 9. Illustration of the findings concerning the left lateral ventricle.

question is completely filled. Some parts of the ventricles are difficult to fill well, and one should not attach, consequently, too much importance to the findings concerning such portions. This is especially true of the inferior horns.

The ventriculograms in the present series showed that the posterior horns are rather variable. All transitions were found, from complete absence to a length of 3 cm. The left posterior horn was absent in five out of thirteen cases, the right in three cases. The X-ray pictures which were used for the study of the posterior horns were taken with the occipital region as the highest portion. Consequently all the intraventricular air will ascend to that posterior portion and outline this completely on the X-ray plate, and an asymmetry in the X-ray picture must be caused by anatomical circumstances and not by defective filling with air.

The difference in the total length of the lateral ventricle varied from 7·11 to 9·5 cm. (regardless of the posterior horn). This difference is hardly greater than one would expect as a normal variation in normal individuals. The posterior portion of the body (*E* on fig. 7) was found to be from 1 to 2 cm. and

also on the ventriculograms the outline of this portion varied as seen in fig. 5. The individual variations of the height of the anterior horn were from 1 to 2 cm., but the outline and shape of this portion were more or less constant.

The average measurements, shown on p. 482, which were found by casts and by dissection, are not quite the same as those shown on p. 485, as a result of the study of ventriculograms.

The inferior horn appears shorter in the ventriculogram, probably because of incomplete filling with air.

The height of the anterior horn on the pneumograms is less than the height found by casting and by dissection, probably because the lowest portion of the anterior horn is narrow and not always well filled with air. In some cases it has been found to be less than 1 cm., while measurements taken by casting and by dissection never showed a lower measurement than 1·6 cm. On the other hand, in ventriculograms, measurements as high as 2 cm. were found which is only 1 mm. less than the highest of those found by the other method. One must, therefore, consider these measurements to correspond quite well.

The distance between roof and floor of the body of the ventricle also shows some variation. The greatest measurement found on the X-ray film was 1·5 cm. for the anterior portion of the body and 1·4 cm. for the posterior portion of the body. The reciprocal measurements found by the other methods were 1·2 and 1 cm. respectively. The lowest measurements were 0·75 cm. for the distance between roof and floor of the body of the ventricle on the pneumogram and 0·5 cm. for the same portion of the ventricle found by dissection and by casting.

The explanation of this difference must be the unavoidable collapse and shrinkage during the fixation. The collapse is obviously of greater importance than the shrinkage, because the total length of the lateral ventricle is very much the same by each method. The average length of the right and left ventricle, decided by study of X-ray plates, was 7·9 cm., and by casting and by dissection 7·87 cm.

The most posterior portion of the ventricle, where the posterior and inferior horns join the body, showed an average measurement of 1·94 cm. The average measurement of the same portion for right and left ventricles, decided by study of X-ray films, was 1·28 cm. The difference is again most likely due to incomplete filling with air. The highest measurement found by X-rays for this portion was 1·8 cm. and by casts 2·1 cm. The lowest measurements were 0·9 and 1·5 cm. respectively. This series is far too small to show how frequently the posterior horns are absent. It shows, however, that asymmetry of the posterior horns is frequently present and that at times one posterior horn is absent while the other is well developed.

The average length of the posterior horn was 1·75 cm. measured by casts and 1·5 cm. measured by X-ray films. The greatest measurement found by the casts was 3·6 cm. and by X-rays 2·7 cm.

The lateral ventricles in relation to the surface of the brain.

The distances from various points of the lateral ventricle to the surface of the brain have been measured. Figs. 10 and 11 show how this has been done. All the distances in fig. 10, except those concerning the inferior horn, have been measured from the surface of the brain at a point 2 cm. from the mid-line.

The two tables on p. 489 show the numbers which were found, and in figs 10 and 11 one can see these findings employed.

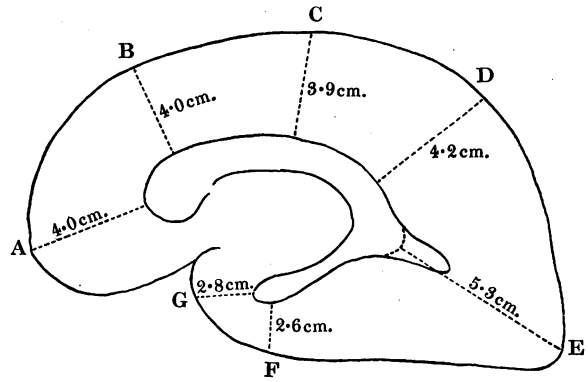


Fig. 10.

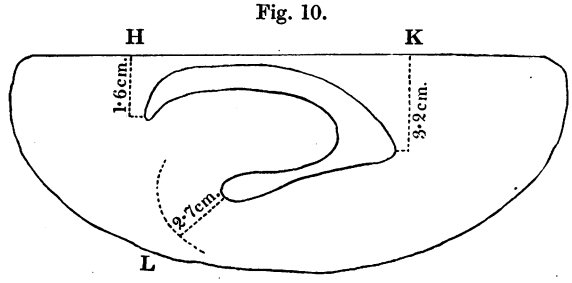


Fig. 11.

Figs. 10 and 11. Illustration of the distance from the lateral ventricle to the surface of the brain which has been decided by the study of X-ray films.

As the findings concerning the distance from the ventricle to the surface of the brain were about the same on the right and left (it does not vary more than 1 mm. anywhere), the measurements for the right side have been used in figs. 10 and 11 and no separate illustration of the left side has been made, as a difference of 1 mm. must be considered to be of little or no practical importance.

Discussion of the findings. The most striking feature in looking at fig. 10 is that the roof of the lateral ventricle follows the outline of the surface of the brain. The lateral ventricle is situated, however, so that the distance from the occipital pole to the posterior portion of the body is 1·3 cm. longer than from the anterior horn to the frontal pole. This figure shows that it is only in the posterior part that there is no "parallelism" between the ventricle and the surface of the brain, and even here the variation is only a slight one.

Such "parallelism" is also true regarding the inferior horn. Figs. 10 and 11 show that the distance from any part of the surface of the temporal pole to the inferior horn is more or less the same (2·6 cm., 2·7 and 2·8).

These figures show, however, that there is also a certain amount of variation of the distances in different individuals. The distance from the anterior horn to the frontal pole may vary as much as 1·3 cm., and the distance from the occipital pole to the posterior portion of the body may vary even 1·8 cm. A similar variation is true of all the other distances, all depending upon whether one is dealing with a large or a small ventricle.

Left ventricle

(All measurements in centimetres.)

	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*K*	*L*
Brain 1	3·5	3·8	4·0	4·0	5·5	3·5	3·5	2·0	3·0	3·5
Brain 2	3·3	3·4		(Compressed)			2·5	1·5	4·0	2·5
Brain 3	4·0	3·5	3·7	4·0	5·5	2·5	2·7	1·3	3·0	2·5
Brain 4	4·0	4·2	4·5	4·3	5·0	2·5	2·7	1·0	2·3	2·5
Brain 5	4·0	3·8	3·5	3·5	5·2	3·0	3·1	2·0	3·8	3·4
Brain 6	4·3	4·0	4·0	3·9	6·0	3·2	3·3	1·6	2·6	3·4
Brain 7	3·2	3·4	3·5	4·0	4·7	2·3	2·6	1·2	2·2	2·7
Brain 8	4·8	5·2	4·2	4·5	6·0	3·2	3·3	1·5	3·0	3·1
Brain 9	4·0	3·9	4·5	5·5	5·5	2·0	3·5	1·8	3·0	3·0
Brain 10	4·0	4·0	4·5	4·5	5·5	2·0	2·3	1·5	3·0	2·5
Average	3·9	3·9	4·0	4·2	5·4	2·6	2·9	1·5	3·2	2·7

Right ventricle

	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*K*	*L*
Brain 1	3·5	4·5	4·5	4·5	5·5	3·4	3·5	2·0	3·0	3·0
Brain 2	3·5	3·5	3·5	3·9	5·0	2·5	2·6	1·5	4·0	2·5
Brain 3	4·5	3·5	3·7	4·0	4·2	2·5	2·6	1·3	3·5	2·5
Brain 4	4·5	4·2	4·5	4·5	5·5	2·8	2·7	1·0	2·5	2·5
Brain 5	3·5	3·5	3·5	3·6	6·3	3·3	3·2	2·0	4·0	3·2
Brain 6	4·2	4·0	4·0	4·0	5·8	3·0	3·2	1·8	2·6	3·0
Brain 7	3·5	3·5	3·0	4·0	5·0	2·4	2·5	1·5	2·9	2·4
Brain 8	4·8	5·0	4·0	4·7	6·0	3·1	3·2	1·5	3·5	3·5
Brain 9	4·0	4·0	4·0	4·5	5·3	1·6	3·0	2·0	3·0	2·5
Brain 10	4·0	4·5	4·3	4·5	5·5	2·0	2·0	1·6	3·0	2·0
Average	4·0	4·0	3·9	4·2	5·3	2·6	2·8	1·6	3·2	2·7

The third and fourth ventricles.

In normal cases the third ventricle presents itself as a mere slit, a few millimetres wide. The majority of anatomical text-books describe the height and length as about equal, 2·5 cm. (Poirier and Charpy, 1921). The study of the third ventricle on the ventriculograms shows that in living humans the antero-posterior axis is somewhat longer than the height, and this form has, therefore, been given the third ventricle on the present model.

The aqueduct of Sylvius is approximately 2 cm. long and runs in an almost vertical direction. In order to strengthen the model it has been given a calibre greater than normal. The above mentioned authors give the length of the fourth ventricle as 3 cm. and the width as about 2 cm. The present model has been made according to this description as it corresponds well with the findings on the ventriculograms.

Description of the model. Because of its neurosurgical purposes, especially in connection with brain puncture and interpretation of ventriculograms, the greatest attention has been paid to the lateral ventricles. The lateral ventricles of the model are the actual casts of brain No. 11 on p. 482. It thus represents the normal ventricle, but according to the X-ray findings it is, perhaps, on the small side but well within normal limits.

On the left lateral ventricle the impression made by the thalamus, the caudate nucleus, the fornix and the splenium corporis callosi have been given separate colours in order to make it easier to visualise the relationship to the

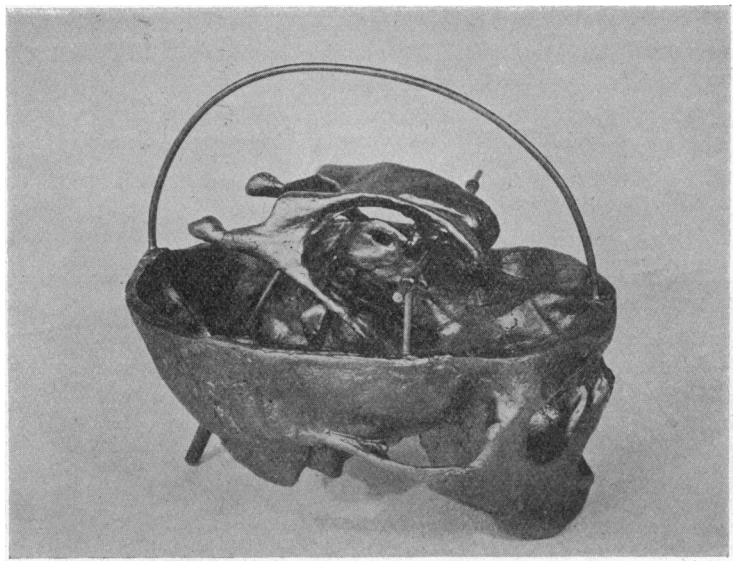


Fig. 12. Illustration of the ventricular model.

neighbouring structures. The lateral ventricle has been divided by black lines into six portions corresponding to units which can be recognised in the antero-posterior view of the ventriculogram. The four ventricles have been carefully placed in their normal positions with relation to each other.

The ventricular system has been placed in a partial cast of a skull of normal size on which a curved wire has been fixed, running from the front to the occiput, indicating the inner surface of the skull.

The ventricles can be moved from side to side in order to make it possible to demonstrate displacement of the ventricles quite clearly.

All pieces have been cast in brass. The model is on sale by the Pilling Surgical Instrument Company, Philadelphia, Pennsylvania.

SUMMARY

The size and form of the lateral ventricles have been decided by eleven paraffin casts and the study of 450 selected sets of ventriculograms.

The results of the examination by the two methods correspond very well but show that a certain amount of collapse takes place in the preparation of the brains.

The lateral ventricles vary to a certain extent in size and form. The greatest variation has been found in the posterior horns where the calcarine fissure at times seems to cause obliteration. The posterior horns are not constantly present, and a unilateral absence of a posterior horn can be seen in normal cases. The rest of the lateral ventricle is constantly present but varies within certain limits in size according to the size of the skull and age of the patient. Concerning the form of the lateral ventricles it has been found that there are normally certain variations of the posterior part of the body.

The investigations show that certain of the pictures and casts which previously have been supposed to represent the normal ventricles illustrate a moderate degree of hydrocephalus.

One of the paraffin casts which was considered to give a good picture of the normal ventricles has been reproduced in brass.

The casts which were obtained from the third and fourth ventricles have not been used for the present model. These parts have been artificially constructed according to anatomical description and ventriculographic findings. The distance from various points of the lateral ventricles to the nearest point at the inner surface of the skull has been measured. A normal skull has been cast in brass, the ventricular system has been placed in the skull and given the normal anatomical relationships.

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