OBSERVATIONS ON THE CEREBROSPINAL FLUID PRESSURE ON SIMULTANEOUS VENTRICULAR AND LUMBAR PUNCTURES

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THE investigations which form the basis of this report were undertaken with the object of determining the relations existing between the ventricular and lumbar cerebrospinal fluid pressures. In the past it seems to have been taken for granted that the pressure within the cerebral ventricles is always in equilibrium with the pressure throughout the entire extent of the spinal subarachnoid space, except, of course, in the presence of spinal block. From time to time, however, it has been suggested that obstruction at the foramen magnum by herniation of the cerebellar tonsils in cases of intracranial tumour might possibly cause a state of partial block. This suggestion has generally been advanced in explanation of the not unusual finding of a normal, or even subnormal, lumbar pressure despite the presence of clinical signs indicative of high intracranial pressure.

Hodgson (1929) reported a series of 49 cases of intracranial tumour which he had investigated by a method described as "combined ventricular and lumbar puncture." He concluded that partial block might result from herniation of the cerebellar tonsils, and he went so far as to say that under such circumstances the initial lumbar pressure might be lower than the pressure in the ventricles. The method he used was as follows. The ventricle was tapped and the ventricular pressure measured. If this pressure was 200 mm. of water or more, cerebrospinal fluid was allowed to escape until the pressure was reduced well below this level. Lumbar puncture was then carried out; the lumbar pressure was measured and, finally, the responses on jugular compression were noted. It will be apparent that the limitations imposed by this method did not allow a determination of the initial simultaneous lumbar and ventricular pressures, and, in fact, Hodgson did not publish any actual figures of the pressure relations in his cases. Furthermore, he used a manometer tube with a bore of 2.0 mm. in measuring the ventricular pressure, and in such a tube a column of fluid 300 mm. in length has a volume of about 1.0 c.c. The displacement of this quantity of fluid is of itself sufficient to cause a variable but definite lowering of the ventricular pressure.

The methods used in the investigations here reported are believed to be free

from these possibilities of error, and the results lead us to conclude that in certain cases of supratentorial tumour the ventricular pressure is greater than the lumbar. Further, it is highly probable that this difference in pressures is causally related to herniation of the cerebral hemisphere through the incisura tentorii.

Method

An initial ventricular tap was carried out in the usual manner. The ventricle chosen was the one which, on clinical grounds, was considered to be on the unaffected side. In every case the operation was carried out under local infiltration anaesthesia. Premedication was not employed. The tap was made with a needle specially designed to guard against loss of fluid and to facilitate the attachment of a manometer tube. Essentially it was a Greenfield lumbar puncture needle, but with a blunt end and the eye laterally placed. When the needle was judged to be within the ventricle the stylet was cautiously withdrawn until fluid was seen to well up around it. At this point the tap was closed and the patient was turned into a lateral position. Lumbar puncture was next carried out, care being taken to avoid loss of fluid. Manometer tubes were then attached to both needles. They were of glass, 300 to 400 mm. in length, and with a uniform bore of 1.0 mm. When necessary the manometer tube was easily extended by adding a second length of tubing by means of a short rubber connector. At this stage the position of the patient and operation table were adjusted in order to bring both needles into the horizontal plane. A piece of board some 3 ft. long and a spirit-level were found convenient for making this adjustment and, as a final check, a water U-tube was used, consisting of two glass tubes connected by several feet of thick rubber tubing.

The pressure relations were investigated in a uniform manner, the various steps of which are conveniently shown in the following tabulation :

- (i) Separate measurement of the lumbar and the ventricular pressures.
- (ii) Both taps opened and measurement of the two columns of fluid. If any difference was noted the position of the needles and menisci was carefully checked with the spirit-level and water U-tube.
- (iii) Bilateral jugular compression, noting the changes effected first in each manometer opened separately and then in both simultaneously.
- (iv) Withdrawal of a measured amount (usually 5.0 c.c.) of cerebrospinal fluid from the lumbar puncture.
- (v), (vi), and (vii) Repetition of steps (i), (ii), and (iii).

In a few instances the critical condition of the patient necessitated a curtailment of the investigations, but in nearly every case the first three steps at least were carried out.

It is, perhaps, as well to emphasize that a column of fluid 300 mm. in length in a tube with a bore of 1.0 mm. represents about 0.25 c.c. of fluid, and the withdrawal of this quantity is insufficient to cause appreciable lessening of the ventricular or lumbar pressures.

Results

Forty-two observations were made on 39 patients. In the accompanying table the cases are classified according to the pressure of the cerebrospinal fluid and the character of the responses on jugular compression.

TABLE I

GROUPS	TOTAL CASES	SITUATION OF TUMOUR		DEATHS
		SUPRATENTORIAL	SUBTENTORIAL	
I : Normal	6	—	—	—
II : Tumours with normal pressures	5	5	—	1 (20%)
III : Tumours with raised pressure and normal dynamics	20	15	5	6 (30%)
IV : Tumours with abnormal dynamics	8	6	2	6 (75%)
Total cases with tumour ..	33	26	7	13 (39·3%)

Group I.—The six patients in the first group were submitted to ventriculography on the suspicion that a space-occupying intracranial lesion was present. Traumatic neurosis, cortical atrophy, and late epilepsy were some of the alternative diagnoses. All the patients were alike in that there was absence of clinical signs of increased intracranial pressure, and in all the cerebrospinal fluid pressures were within the range commonly accepted as normal. One patient, suffering from a traumatic neurosis, had a lumbar pressure of 170 mm. of water; in the others the pressures varied between 100 and 145 mm. of water.

In all the patients of this group the initial lumbar and ventricular pressure were equal and the responses on jugular compression were prompt, synchronous, and of equal range.

Group II.—The five patients in the second group all had intracranial tumours, proved at operation. The highest cerebrospinal fluid pressure recorded in this group was 185 mm. of water; this was in a man who had a left parietal meningioma weighing 130 gm. The lowest pressure recorded was 90 mm. of water in a patient who had a deeply placed right temporal cystic glioma.

It is of some interest that three of the five patients of this group had supratentorial meningiomas which were successfully removed.

The initial ventricular and lumbar pressures were equal, and they remained equal through the various stages of the test. The responses on jugular compression were prompt and of equal range and on release the return to the resting level was immediate.

Group III.—The 20 patients in the third group all had intracranial tumours and in them the cerebrospinal fluid pressures were abnormally high (200 mm. of water or more). The raised cerebrospinal fluid pressure constituted, however,

the sole abnormality of the cerebrospinal hydrodynamics, for the ventricular and lumbar pressures were equal in all the circumstances imposed by the tests employed. Particular importance attaches to the five examples of subtentorial tumour in this group. In four of these five cases there was either operative or post-mortem verification of the tumour, and in all four herniation of the cerebellar tonsils was very great (Fig. 1). Nevertheless, this herniation through the foramen magnum was not accompanied by any inequality of the lumbar and ventricular pressures, neither did it cause any retardation in the responses to jugular compression.

Of the 15 examples of supratentorial tumour, three were examined post mortem and in two of these three some degree of tonsillar herniation was present; in only one of them was there any post-mortem evidence of tentorial herniation, and it was of the slightest degree. Moreover, the patient survived the investigation by rather more than three weeks, and it is at least possible that the tentorial herniation occurred in the last weeks of life.

Group IV.—The eight patients comprising the fourth and important group are those who showed some abnormality of the cerebrospinal hydrodynamics apart from a simple increase of pressure. The essential data relating to these cases are set out in Table 2.

Two patients (Cases 7 and 8) showed a relatively slight abnormality, which consisted of a definite retardation in the lumbar response to bilateral jugular compression. In the other six patients an initial difference in the lumbar and ventricular pressures was found, and, except in Case 2, this more striking abnormality was always accompanied by a marked retardation in the lumbar response to jugular compression.

In the six patients in whom the ventricular pressure was initially greater than the lumbar, the disparity varied from 20 mm. to as much as 100 mm. of water. In all cases except Case 4, in which only 2 c.c. of fluid were removed, the withdrawal of fluid from the lumbar sac accentuated the disparity. Only one of these six patients had a subtentorial tumour, and this patient had bilateral auditory neurofibromata.

In all five cases where the tumour was supratentorial, there was clear post-mortem proof of herniation of the ipsilateral temporal lobe through the incisura tentorii (Fig. 2), and of a greater or less degree of pressure upon the contralateral crus (Kernohan and Woltmann's notch). In this connection it is perhaps as well to point out that the tonsillar pressure cone is much more easily demonstrated post mortem than the tentorial herniation. The post-mortem technique used at the National Hospital (the cadaver in the prone position with the head flexed over a block) permits an excellent exposure of the contents of the posterior cranial fossa and upper cervical vertebral canal, and shows the disposition of the parts *in situ*. Thus, even slight degrees of tonsillar herniation are at once apparent. There is, unfortunately, no means of obtaining a comparable exposure of the region of the incisura tentorii. Here one must depend solely on the appearances after removal of the brain, and it is highly probable that tentorial herniations become less evident, just as is the case with the tonsillar herniation.

TABLE II.—CASES SHOWING

CASE	DISEASE	PRESSURES BEFORE WITHDRAWAL OF FLUID (MM. OF WATER)					FLUID REMOVED FROM LUMBAR PUNCTURE
		MEASURED SEPARATELY		MEASURED SIMULTANEOUSLY		BILATERAL JUGULAR COMPRESSION	
		LUMBAR	VENTRIC.	LUMBAR	VENTRIC.		
1. J. C., 37 ..	L. frontal glioma (cystic).	280	310	240	300	Lumbar: slow rise to 300. Ventric.: quick rise to 480.	5 c.c.
2. F. M., 30	L. temporal lobe abscess (otitic).	360	450	350	450	Lumbar: fairly quick rise to 450. Ventric.: quick rise to 600.	5 c.c.
3. L. W., 31	R. parietal glioma.	385	430	—	—	Lumbar: slow rise. Ventric.: prompt rise.	5 c.c.
4. F. R., 40..	Large middle fossa meningioma.	330	370	310	330	Lumbar : slow rise to 400. Ventric.: quicker rise to 500.	2 c.c.
5. M. D., 29	R. occipital glioma.	490	460	340	360	Lumbar: slow rise. Ventric.: quicker rise.	5 c.c.
6. M. C., 29	Bilateral VIII N. neurofibromata.	320	340	300	320	Lumbar: slow rise to 350. Ventric.: quick rise to 420.	5 c.c.
7. A. C., 44	R. parietal tumour.	345	345	—	—	Lumbar: slow rise to 360. Ventric.: quick rise to 400.	5·2 c.c.
8. H. B., 65	Posterior fossa tumour (unverified).	95	95	—	—	Lumbar: slow rise to 150. Ventric.: quick rise to 300.	3 c.c.

Note.—In Case 5 it will be observed that the initial lumbar pressure was higher than pressure became greater than the lumbar, and this excess of ventricular pressure persisted doubt that the latter readings were a true index of the pressure relations.

ABNORMAL DYNAMICS.

PRESSURES AFTER WITHDRAWAL OF FLUID (MM. OF WATER)					EXCESS OF VENTRIC. PRESSURE		REMARKS
MEASURED SEPARATELY		MEASURED SIMULTANEOUSLY		BILATERAL JUGULAR COMPRESSION	BEFORE WITHDRAWAL	AFTER WITHDRAWAL	
LUMBAR	VENTRIC.	LUMBAR	VENTRIC.				
120	220	140	210	Lumbar: slow rise to 170. Ventric.: quick rise to 340.	30	100	Died same day. Tentorial and ton- sillar herniation.
210	(?) patient restless.	—	—	—	100	—	Died within 24 hours. Severe tentorial herniation but no tonsillar hernia- tion.
230	285	—	—	Block more evident.	45	55	Died same day. Tentorial and ton- sillar herniation.
270	300	270	300	As before.	40	30	Death 3 weeks later. Severe obstruction at the tentorium. No tonsillar herniation.
200	250	200	250	As before.	20	50	Death within 24 hours. Severe tentorial herniation, no ton- sillar herniation.
220	260	240	270	As before; indication of block more marked.	20	40	Died 2 days later. Large tumours filling both cere- bello-pontine angles. No ton- sillar herniation.
140	140	—	—	Lumbar: very slow rise to 160. Ventric.: quick rise to 400.	—	—	Discharged from hospital I.S.Q.
30	30	—	—	As before.	—	—	Discharged from hospital I.S.Q.

the ventricular. However, when both taps were open simultaneously the ventricular and was increased after withdrawal of fluid by the lumbar route. We have little

Cases 7 and 8 showed merely a retardation in the rise and fall of the lumbar pressure on jugular compression. Both patients were discharged from hospital and final verification of the tumours is lacking. In Case 7 the clinical findings and the exploration of the right cerebral hemisphere gave almost certain proof of the existence of a deep temporo-parietal tumour. Case 8 was an old and feeble woman; following ventriculography a suboccipital decompression, without exploration, was carried out for the relief of the high intracranial pressure.

Discussion of Results

It is apparent that the observations here recorded afford conclusive proof that the lumbar and ventricular pressures are not of necessity always equal. A difference was observed only in cases where the lumbar pressure was abnormally high. It seems, therefore, that a normal lumbar pressure in a case of intracranial tumour is a true index of the intracranial pressure. In Case 8 the patient had an acute papilloedema of three dioptries, and the lumbar pressure, although only 90 mm. of water, was identical with the ventricular pressure.

Although the maximum difference of pressure did not exceed 100 mm. of water, the clinical course of the patients indicates that a considerably smaller difference of pressure is of grave significance.

The conditions determining the occasional inequality of pressures are worthy of further consideration. Of 33 patients suffering from intracranial tumour, there were six in whom the ventricular pressure exceeded the lumbar. In five of these six patients the tumour was situated above the tentorium, and without exception there was definite post-mortem evidence of herniation of the ipsilateral temporal lobe through the incisura tentorii. In contrast with these observations are the findings in four patients suffering from proved subtentorial tumour. In them, despite marked and in some cases extreme tonsillar herniation, the lumbar and ventricular pressures were equal under all the conditions imposed by the several tests employed. Furthermore, the lumbar and ventricular responses to bilateral jugular compression were equal in all respects.

When these investigations were begun it seemed reasonable to anticipate that herniation through the foramen magnum might cause some degree of block. The normal pressure relations in cases of subtentorial tumour which were associated with severe tonsillar herniation came, therefore, as something of a surprise, particularly as certain very abnormal observations were recorded in cases of supratentorial tumour. Case 8, a patient with an unproved though almost certain subtentorial tumour, showed, it is true, a distinct lag in the rise of lumbar pressure on jugular compression, and it may be that had a greater number of cases of subtentorial tumour been examined more would have shown some degree of abnormality of the cerebrospinal hydrodynamics other than a simple increase of pressure. Two factors, however, reduced the number of patients with subtentorial tumour available for study. First, a large proportion of subtentorial tumours occur in children, with whom co-operation is difficult or impossible, and secondly, in subtentorial tumours in adults ventriculography is not often necessary.

The only proved case of subtentorial tumour showing a difference in the

lumbar and ventricular pressures was a patient with large bilateral auditory neurofibromata. In addition, there were numerous small neurofibromata on the posterior spinal roots. None of these was sufficiently large to have caused a block, and we believe that the inequality in the lumbar and ventricular pressures must be related to the auditory nerve tumours. However, there is obviously a great difference between a unilateral neurofibroma or a midline cerebellar tumour and tumours filling up both cerebello-pontine angles. Indeed, it is plain that the mechanical effects produced by the obliteration of both angles, together with probable coincident compression of the iter of Sylvius, would not be far removed from those brought about by herniation of the temporal lobe downwards through the incisura tentorii. For these reasons the observations in this case can hardly be advanced as evidence in favour of tonsillar herniation being a usual cause of fluid block.

Assuming that tentorial herniation stands in causal relation with a ventricular pressure in excess of the lumbar, it is advantageous to consider the manner in which such a disparity in pressures is likely to be produced. The factors in operation can best be illustrated by considering the probable stages in the evolution of a unilateral supratentorial tumour. In the earlier stages of the growth of such a tumour, the affected cerebral hemisphere increases in bulk at the expense of the adjacent subarachnoid cisterns. As Spatz and Stroescu (1934) have shown, this is at first, in all probability, a passive process, but at a later stage the ever-increasing demand for space leads to complete obliteration of the cisterns and, particularly, of the cisterna ambiens (the subarachnoid cistern encircling the mid-brain). The obstruction in this situation corresponds with that experimentally produced in dogs by Dandy (1919). He found that the production of adhesions around the mid-brain invariably led to the development of hydrocephalus. The obliteration of the cisterna ambiens, on the basis of Dandy's experiments, affords a reasonably adequate explanation for a general increase of intracranial pressure, but the resulting obstruction to the upward flow of cerebrospinal fluid does not, of course, account for a disparity of pressures above and below the tentorium. The increasing bulk of the cerebral hemisphere, however, would serve to force the medial border of the temporal lobe, lying as it does immediately above the incisura, downwards through the incisura tentorii. In this way a frank tentorial herniation is produced, and as it progresses it is likely that the iter of Sylvius becomes obliterated, or at least so compressed that it is inadequate to equalize the pressures above and below the tentorium. In such circumstances the pressure in the posterior cranial fossa is not necessarily the same as the pressure above the tentorium, and it may well be lower because of possible absorption of cerebrospinal fluid below the tentorium. In our opinion this would explain the occurrence of a lumbar pressure which is lower than the pressure in the ventricles. In short, it is suggested that obliteration of the cisterna ambiens is the cause of the simple increase of intracranial pressure observed in the cases comprising Group III, and that a superadded compression of the iter of Sylvius is the factor responsible for the disparity of pressures which was found in the cases in Group IV.

The observations made in cases of subtentorial tumour with severe tonsillar herniation give strong warrant for the belief that the lumbar pressure is identical with the pressure in the posterior cranial fossa, and therefore justify the assumption that lumbar and ventricular punctures give a true indication of the pressures below and above the tentorium. It should be noted, however, that the pressure in the cisterna magna was not measured in any of the cases. Cisternal puncture is hardly justifiable where there is a suspicion of raised intracranial pressure.

These observations warrant some further consideration because of the bearing they have on prognosis and treatment. An inspection of Table I shows that the mortality rate was 30 per cent. in Group III, in which the only abnormality was a raised intracranial pressure, whereas it was 75 per cent. in Group IV, in which an additional abnormality in the cerebrospinal hydrodynamics was present. In Group IV, of the six patients with a difference of lumbar and ventricular pressures, four died within 24 hours of investigation. In three of the cases (Cases 1, 3, and 5), this rapidly fatal issue followed a simple decompression and in the fourth case (Case 2) after nothing more than a ventricular tap. It is highly probable that the tentorial herniations were largely responsible for the early death in these four cases. In the other two cases death was delayed; in Case 6 it occurred 2 days later from the severity of the operation, and in Case 4 after 3 weeks from the natural course of the disease. This mode of death is in marked contrast with that in the six patients in Group III, in whom the only abnormality of the cerebrospinal hydrodynamics was a raised intracranial pressure. Of these six patients all but one survived operation by more than 3 days, and death was due to the natural progress of the disease. The early death on the second day in one patient was due to the effects of a radical tumour removal.

This study of the mortality figures for the several groups, even though based on relatively few cases, suggests the gravity of a tentorial herniation. While it is probable that the sudden death which has long been known to occur in cases of unrelieved cerebellar tumour is due to medullary compression associated with tonsillar herniation, the gravity of tentorial herniation has only recently been recognized. In this connection it is interesting to consider certain collateral evidence which has recently accumulated.

Herniation of the brain through the incisura tentorii and the foramen magnum was well known to Collier (1904), and the existence and significance of notching of the crus was pointed out by Kernohan and Woltmann (1929). These writers, however, were principally concerned with the false localizing signs which accompanied these conditions. Clovis Vincent, David and Thiébaut (1936) appear to have been the first to stress the great danger of tentorial herniation, and David and Askenasy (1937) gave a graphic account of the clinical course in such cases. They stressed the danger of lumbar puncture and urged that ventricular puncture was a procedure of much greater safety. Even ventricular puncture was, in their opinion, by no means devoid of risk, and they advised that it should only be done as an immediate preliminary to operation. Finally, they urged the importance of searching for the tentorial herniation

during operation and, if possible, disimpacting it. In two of their cases where rapidly increasing coma followed on radical operation for supratentorial tumour, they re-explored the brain and successfully liberated a herniated temporal lobe. The clinical course of the cases with tentorial herniation here reported bears out their contentions. Furthermore, withdrawal of cerebrospinal fluid accentuated the disparity between the lumbar and ventricular pressures, and the implication of this requires no emphasis. In the experience of one of us (W. R. H.) ventriculography, when not followed by immediate operation, has in several instances proved fatal within 24 to 48 hours. In these cases the tumours were supratentorial and it appears that the risk of ventriculography, contrary to what is often stated, is much greater in cases of supratentorial tumour than it is in the presence of hydrocephalus caused by subtentorial tumour.

Massive ponto-mesencephalic hæmorrhages, which are known to occur in the presence of supratentorial tumours when associated with tentorial herniation, are of considerable significance when considered in the light of the present observations. Van Gehuchten (1937) reported six cases, and in all of them the tumours were supratentorial and the degree of tentorial herniation severe. In four of the cases death appeared to follow lumbar puncture or ventriculography. He was in entire agreement with David and Askenasy regarding the dangers attendant on lumbar puncture. Moore and Stern (1938) collected 10 cases of massive ponto-mesencephalic hæmorrhage in 130 consecutive cases of intracranial tumour examined post mortem at the National Hospital. The presence or absence of tentorial herniation was not stated in every case, but it was present in the majority. In all the 10 cases the hæmorrhage appeared as a terminal event and it had no specific connection with lumbar puncture, ventriculography, or operation. The character of these hæmorrhages was remarkably constant. In all cases they were arterial or at least arteriolar, and occurred chiefly from the long central ascending branches of the basilar artery. Van Gehuchten and Moore and Stern all sought the reason for the occurrence of the hæmorrhages in the increased intracranial pressure, and they suspected that tentorial herniation played an important part in their causation.

It appears to us that a disparity in the intracranial pressures above and below the tentorium may partly explain the occurrence of ponto-mesencephalic hæmorrhage, for the conditions which appear to determine the hæmorrhage are exactly those which were found in our cases to be associated with a difference of lumbar and ventricular pressures. At first sight it appears strange that no instance of ponto-mesencephalic hæmorrhage was met with in the present series, but it is to be remembered that of the six cases in Group 4 who showed a disparity of pressures, all but one had some form of decompression. Some of the recorded cases of ponto-mesencephalic hæmorrhage, on the other hand, had ventriculography which was not as a rule followed by operation. The hæmorrhage, in fact, appeared as a terminal event in cases of unrelieved high intracranial pressure. It appears that a continued excess of ventricular over subtentorial pressure is a factor the importance of which should not be ignored in any hypothesis which seeks to explain the occurrence of these ponto-mesencephalic hæmorrhages.

If the intracranial circulation is to remain adequate in states of increased intracranial pressure, some adjustment of the general arterial pressure must occur to meet the requirements of the raised intracranial pressure. Assuming that the arterial pressure is uniform throughout the intracranial cavity, an arterial pressure which is adequate for the region of highest intracranial pressure would presumably be excessive in a region of relatively lower intracranial pressure. When the intracranial pressure is lower below than above the tentorium, there will be an excessive difference between the arterial and the cerebrospinal fluid pressures in the posterior cranial fossa, and when this difference becomes sufficiently great it will cause stretching of the arterial wall and hæmorrhage; and, indeed, Moore and Stern point out that the pathological features of ponto-mesencephalic hæmorrhage complicating supratentorial tumour are identical with those seen in ordinary hypertensive apoplexy.

It is suggested, therefore, that ponto-mesencephalic hæmorrhages occurring in cases of supratentorial tumour are the result of a relative arterial hypertension, which is due to the fact that the intracranial pressure is lower in the posterior cranial fossa than it is above the tentorium.

Summary and Conclusions

The relationship between the lumbar and ventricular cerebrospinal fluid pressures has been investigated on 41 occasions in a series of 39 patients, the majority of whom were suffering from intracranial tumour.

Six of the patients had no gross intracranial disease, and in them the lumbar and ventricular pressures were identical when measured separately, simultaneously, on bilateral jugular compression, and after withdrawal of lumbar fluid.

All the other patients, except one, had proved intracranial tumours. In five of them the initial lumbar pressure was within normal limits and in 20 the lumbar pressure was above 200 mm. of water; in all 25 cases the lumbar and ventricular pressures and the responses to jugular compression and after withdrawal of fluid were identical. In the remaining and important group of eight cases, six showed an initial difference between the lumbar and ventricular pressures, the ventricular pressure being from 20 to 100 mm. higher. This disparity was accentuated by withdrawal of lumbar fluid, and in all eight cases jugular compression revealed a partial block.

A difference between the lumbar and ventricular pressures was associated with a high early operative mortality and with post-mortem evidence of herniation of the temporal lobe through the incisura tentorii. Tonsillar herniation through the foramen magnum, on the other hand, did not produce any difference of pressures.

The significance of these findings is discussed as regards the importance of tentorial herniation in relation to the possible dangers of lumbar puncture and ventriculography, and as an important factor in causing early post-operative death. Furthermore, the occurrence of tentorial herniation, associated with

an inequality of supratentorial and subtentorial pressure, is believed to be an important factor in causing the ponto-mesencephalic hæmorrhage which may occur as a terminal event in cases of cerebral tumour with unrelieved high intracranial pressure.

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REFERENCES

- Collier, James (1904). *Brain*, **27**, 490.
 Dandy, W. E. (1919). *Ann. Surg.*, **70**, 129.
 David, M., and Askenasy, H. (1937). *J. Belge Neurol. Psychiat.*, **37**, 550.
 Van Gehuchten, P. (1937). *Encéphale*, **32**, ii, 113.
 Hodgson, J. S. (1927). "The Intracranial Pressure in Health and Disease" : The Association for Research in Nervous and Mental Disease, **8**, 182.
 Kernohan, J. W., and Woltmann, H. W. (1929). *Arch. Neurol. Psychiat.*, Chicago, **21**, 274.
 Moore, M. T., and Stern, K. (1938). *Brain*, **61**, 70.
 Spatz, H., and Stroescu, G. J. (1934). *Nervenarzt*, **7**, 425.
 Vincent, Cl., David, M., and Thiébaud, F. (1936). *Rev. Neurol.*, **65**, 536.

Fig. 1.—Posterior view of cerebellum showing downward herniation of the cerebellar tonsils

Fig. 2.—The brain from a case of left temporal abscess (Case 2) showing a severe tentorial herniation and dislocation of the midbrain to the opposite side. The impression of the edge of the tentorium is indicated by the arrows A. Note the slight accentuation of the normal groove (B) on the right uncus.