Change of Pressure in Cranium following Various Operations on the Brain*

The Second Report of Studies about Pressure in Cranium

By

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We need not emphasise that the change in the pressure in cranium (abbreviated as PIC hereunder) following a neurosurgical operation has a close bearing on the after-treatment and the prognosis of the patient, but we have the impression that in the past merely symptomatic measures have been resorted to, based upon scanty inferences on the PIC drawn with the general conditions, the pulse, the breathing, the blood pressure, the temperature etc. of the patient, as clueses.

In our Surgical Clinic under Prof. Katsura, however, we have for some years obtained excellent results by applying timely and most appropriate postoperative measures indicated by the measured PIC. In the meanwhile, we could observe some interesting findings in the post-operative change of PIC specific to various surgical brain diseases.

And our observations on PIC to reduce intracranial pressure with hypertonic glucose solution applied intravenously and relationship of PIC and headache, consciousness will be described.

EXPERIMENTAL

Method and Materials

As previously reported1,2) in my paper, we have been using an easily manipulated device for measuring the PIC, attached to a polyethylene tube which can be inserted into the lateral ventricle of one side through the forehead or occiput.

5 cases of corticotomized epilepsy genuina, 20 cases of benign supratentorial tumors, 13 cases of benign subtentorial tumors, 2 cases of malign supratentorial tumors, 3 cases of malign subtentorial tumors, 1

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case of brain abscess, 4 cases of metastatic brain tumors, 6 cases of hypophyseal tumors and 4 cases of brain injuries etc., or 58 cases in total (excluding pneumoventriculography) of which we will hereunder report on the results obtained in representative cases, for contributing something to serve as guide in the future.

Results

1) Change of PIC following corticoectomy in cases of genuine epilepsy
The change of PIC following excision of unilateral area 6αβ of casey, of genuine epilepsy, a disease that can be said to accompany scarcely any organic degeneration of the brain, was as shown in Fig. 1. In such cases the PIC rose to the maximum in 30 to 40 hours after the operation, and at the highest, the value usually remained below 300 mm.H₂O. Thereafter, the PIC subsided gradually, recovering the normal level in 70 hours or so. Thus, in a moderate surgical invasion as in the above cases, we have not to make much of a heightening of PIC due to brain edema, and a dehydrating measure by means of intravenous administration of hypertonic glucose solution in such a case is little effective in lowering the PIC but in some cases it positively though slightly raises the pressure. (Fig. 1)

2) Change of PIC following extirpation of benign supratentorial tumors

![Graph](image-url)
Studies about Pressure in Cranium. II

Such tumors comprise locally circumscribed ones as parasagittal meningioma and unlocalised ones as benign glioma, and the behavior of the PIC subsequent to operations for excising such tumors showed difference by their kinds.

When unlocalized glioma was operated upon, the PIC ran up to 500 mm.\(\text{H}_2\text{O}\) in a short time after the operation in some cases and in the other, rose to the same level but slowly within some 30 hours, but at any rate, the maximum rarely exceeded 600 mm.\(\text{H}_2\text{O}\). The value rose to the highest in 30 to 60 hours after the operation and began to subside from around the 70th hour to the level of nearly 350 mm.\(\text{H}_2\text{O}\). (Case 1)

A tumor of this kind tending to be diffusive are hardly extirpated wholly by operation, and it is undeniable that the cerebral edema is severe in such a case. High concentration glucose solution injected intravenously is considerably effective in reducing the PIC, which temporarily falls by 200 to 300 mm.\(\text{H}_2\text{O}\), but in an hour after the injection, it rises to the pre-injection value or even above it in some cases. (Fig. 11) Thus, seeing that the PIC reducing action of hypertonic solution is only transient and that brain edema reappear secondarily thereafter, some\(^5\) deny the utility of the injection, but when the PIC is constantly heightened and the blood circulation is obstructed, it may be an effective means to prolong the state of disturbed brain function for even a short time, to reduce the PIC, were it only transiently, and assure improved blood circulation in the brain. Shenkin\(^4\) recommends intravenous injection of hypertonic glucose solution as a better method than brain puncture, for the former is effective in improving the blood circulation. A repeated injection, however, should be applied with care, as it may induce general dehydration to the detriment of the patient.

Following extirpation of localized slow-developing tumors, such as cerebral meningioma, the rise of PIC is smaller than in the preceding, being not much different from the state following corticoectomy of epileptic cases, except that the recovery of the normal PIC level comes somewhat later. (Case 2)

Case No. 1 (Fig. 2)

X. Aomatsu. Girl of 12 years old. Ependymoma in the left parietal region.\(^5\) After the operation, the PIC gradually rose to 460 mm.\(\text{H}_2\text{O}\) in 9 hours, severe headache was complained of and the patient showed signs of uneasiness, complaining of hallucinations of small animals. 100 cc of 50% glucose solution was injected intravenously, her PIC lowered by about 200 mm.\(\text{H}_2\text{O}\) and the patient was relieved to some extent of hallucination and headache. The PIC rerose in about one hour, but her headache remained alleviated somewhat longer. In about 50 hours after the operation, the PIC began to fall, gradually coming down to around 350 mm.\(\text{H}_2\text{O}\) and the patient left the hospital.
24 days after the operation, entirely cured. When the rise of PIC is of this extent, the changes in pulsation, respiration and blood pressure remain independent of the change in PIC, and we could not confirm any sign of Cushing's phenomenon.

Fig. 2. Case No. 1 X. Aomatsu. Ependymoma in the left parietal region. Extirpation. (see text).

Case No. 2 (Fig. 3)

X. Ishikawa. Male. 41 years old. Meningioma in the left parietal region. The tumor was a parasagittal meningioma of the size of $8 \times 6 \times 3$ cm. It was extirpated completely, though the operation was accompanied by rather profuse bleeding.

After the operation, the PIC rose slowly, attaining 200 mm. H$_2$O in 20 hours and to the maximum of 300 mm. H$_2$O in 39 hours, but did not come down to any perceptible extent thereafter, always fluctuating between 200 and 250 mm. H$_2$O. His consciousness was not entirely disturbed during his course of recovery, complaining of headache, and was discharged clinic completely cured 50 days after the operation.

3) PIC following excision of malign supratentorial tumor

When the supratentorial tumor is a malign diffusive glioma, it is difficult to extirpate it entirely in most cases, and when a part of it is left un-excised, a very serious rise of PIC follows the operation. Even repeated ventricle puncture cannot prevent a steep rise of PIC to something more than 1,000 mm.H$_2$O. A treatment with hypertonic glucose solution for dehydration brings only transient relief, the PIC soon rising to a level higher than before the treatment. In such case, however, this serious rise of PIC is survived and the general conditions show improvement,
the PIC begins to subside in around 80 hours after the operation and finally stabilizes between 500 and 600 mm. H$_2$O.

Case No. 3 (Fig. 4)

X. Sato. Male. 46 years old. Glioblastoma multiforme of the right parietal region. Upon opening the upper right temporal region a diffusely developed tumor was found and excised as wholly as possible. After the operation, his consciousness began to be turbid, vomiting became frequent and his PIC rose makedly. Attempts to control the rise of PIC by intravenous injection of 50% glucose solution proved ineffective and in 21 hours, the PIC rose to exceed 800 mm. H$_2$O. Then, about 8 cc of cerebrospinal fluid was extracted to depress the PIC, but presently it began to rise again. Such treatments were repeated more than a dozen times, when the patient gradually recovered consciousness and his PIC began to show stabilization at 500 mm. H$_2$O. Thereafter, a deep-sited irradiation with 3,000 r. of X-ray led to gradual alleviation, and the patient recovered so far as to be fully capable of walking and was discharged from our clinic in 2 months after the operation.

4) PIC following extirpation of benign subtentorial tumor

Tumors inside the tentorium always more or less obstruct the ventricular system, particularly frequently the aqueduct of Sylvius, and it may be fairly said that the result of operation on such a tumor depends on the success in removing this obstruction to open up the canal. When the success is complete, the PIC decreases and shows no perceptible rerise thereafter. Frequently after the operation a moderate rise of PIC, which forces open the aqueduct and thus drops abruptly, is followed by a sudden improvement of the patient’s conditions. (Case 4) Accordingly, we may
even say that the success or failure of the operation may be evaluated from the post-operation PIC curve. On the other hand, in the case when the operation has not succeeded in eradicating the tumor and in opening up the obstructed aqueduct of Sylvius, the PIC remain high for a long time and though the progress of the disease may be held up temporarily, no positive improvement sets in, the brain edema growing worse. (Case 5) In such a case, a reoperation or a Torkildsen's operation should be considered as soon as possible. Little effect can be expected from injection of hypertonic glucose solution in a case of subtentorial tumor, the PIC being suppressed by 100–150 mm. H₂O at the highest in 30 minutes, but rising to the original level or higher in an hour. This is seemingly due to the fact that the high PIC in such cases is not caused by edema of the cerebrum, but by disturbed circulation of the cerebrospinal fluid by the obturation of the ventricular system. (Fig. 11)

Case No. 4 (Fig. 5)

X. Sato. Male. 36 years old. Meningioma in the right cerebellum.

Upon opening his lower occiput, a walnut-size tumor rich in blood vessels was found in the right cerebellum. Though the operation was accompanied with rather heavy bleeding, the tumor was successfully eradicated. Following the operation, his PIC rose and reached 350 mm. H₂O in 21 hours, but fell abruptly thereafter, to come down to the level of 150 mm. H₂O in 27 hours after the operation. Then he forgot all headache, that was so heavily felt before, began to show good appetite, and without showing sign of rise of the PIC, discharged from our clinic on the 43rd day, quite relieved.
Fig. 5. Case No. 4 X. Sato. Meningioma in the right cerebellum. Extirpation. (see text).

Case No. 5 (Fig. 6)

X. Takamura. Male. 56 years old. Right acustic tumor. Upon opening the right lower occiput, a thumb-tip size tumor was found in the cerebello-pontine angle, but on account of profuse bleeding, we failed in full eradication of the tumor. 6 hours after the operation, his PIC was found fluctuating near the level of 350 mm. H₂O, but showed no signs of coming down. The patient was not relieved of his headache and vomiting, his visual acuity and his hearing fell lower and lower, no improvement in his conditions was brought about, and he was discharged from the hospital about 9 months after the operation, with his both eyes totally blind and his both ears nearly deaf.

5) PIC following excision of malign subtentorial tumor

It is difficult to extirpate such a tumor infiltrating diffusely, and usually we have to leave the obstruction of the ventricular system not satisfactorily broken through, but after the operation, the PIC never was found to rise to the high as shown in the cases with malign supratentorial tumors. This is probably due to the fact that, just a slow-progressing incomplete but not a sudden and complete uretral obturation induces hydronephrose, so an abrupt and complete closure of the ventricular system acts in inhibiting the secretion by the choroid plexus and suppressing to rise of the PIC, though of course a temporary heightening of PIC must occur, as the ventricular system is obturated speedily and completely by the fast-growing malign tumor. On the other hand, it is perhaps due to the slow closure of the ventricular system that higher PIC appears more frequently in the cases with benign subtentorial tumors. As in such cases, the effect of intravenous injection of hypertonic glucose solution is not perceptibly
manifest in the cases with malignant subtentorial tumors.

Case No. 6 (Fig. 7)

X. Saito. Boy of 7 years old. Medulloblastoma in the cerebellum. Upon opening the lower occiput, a soft tumor was found infiltrating the bilateral hemisphere of the cerebellum diffusively, covering the vermis cerebelli, and only a biopsy was taken. Thereafter, his PIC rose barely to 200 mm. H₂O, at the highest, but the patient frequently fell into fits of unconsciousness and spasms. Deep X-ray irradiation brought relief and was discharged from our clinic 50 days after the operation. He is said to be able to play harmonica at present.

6) PIC following operation on inflammatory tumor and metastatic brain tumor

In a case of inflammatory brain tumor, severe brain edema naturally follows and the PIC rises to a considerable height. Of course surgical operation in such a case should be attempted only when the acute stage has passed, a capsule has surrounded the tumor and the brain edema has abated, but since the operational process itself is followed often with considerable brain edema, a rise of PIC similar to that in the case of malignant cerebral glioma is always observable. (Case 7) When a metastatic brain tumor has turned into an abscess or has diffusively invaded the brain, the PIC rises to an excessive height and shows a curve like that after operation on malignant supratentorial glioma. (Case 8) When, however, no abscess is formed or the tumor is rather localized, the PIC rises only to
the extent as if a benign supratentorial tumor is present.

Case No. 7 (Fig. 8)

S. Yokota. Female. 26 years old. Brain abscess. Thus, opening the right parietal region an abscess of egg-size located dorso-cranial to the Sylvius's fissure was found. It content was aspirated and a rubber drain was inserted. A culture of the pus revealed presence of streptococci. After the operation, her PIC rose rashly to exceed the 1,000 mm. H₂O mark, and removal of the cerebrospinal fluid was resorted to lower its pressure and to circumvent crises, and finally the PIC subsided to 500-600 mm. H₂O. Her consciousness returned to clarity, complaints of headache were heard no more, her appetite improved and unaided walking became possible. On the 85th day after the operation, she was discharged from our hospital.

Case No. 8 (Fig. 9)

X. Mawatari. Female. 37 years old. Metastasis of primary pulmonary cancer to cerebrum. Trepanation was made on her right forehead and the dura-mater was resected. Brain edema was found in a severe degree and by puncture about 3 cc. of pus was extracted. At the bottom of the puncture, a hard tumor closely adhering to the cerebrum was found which seemed to be diffusely infiltrating as far as to the opposite side. This tumor was excised as much as possible. After the operation, the PIC rose soon to exceed 1,000 mm. H₂O, the patient's consciousness was impaired and continued draining of cerebrospinal fluid existed for 14 days without no relief, and after 60 days of unrecovered consciousness and general marasm, she succumbed to death. Upon autopsy, a goose-egg size cancer of glandular type was found in the middle lobe of her right lung.
7) Surgical brain diseases apt to be followed by low PIC after operation

As previously reported, there are cases where the PIC does not rise but lower after the operation, causing symptoms similar to the case when the PIC rises. Such drop of PIC is frequently seen after operation for diseases of the chiasma region and for chronic subdural hematoma.
7 such cases among 58 cases, i.e., 3 among the 6 cases of diseases of the chiasma region, 2 cases of subdural hematoma, 1 case of brain injury, and 1 case of tumor in the 3rd ventricle, were encountered. It is interesting that cases of lowered PIC are often found among patients with internal hydrocephalus following pneumoventriculography. Such depression of PIC can be fairly prevented when after the operation, the spaces in the cranium are filled up with physiological saline solution and the dura mater is sutured, but when even such precautions cannot prevent subnormal PIC, we must infer that there is some disturbance in the production and absorption of the cerebrospinal fluid. The cause and treatment of such cases, have been reported previously.9)

Case No. 9 (Fig. 10)

X. Ejiri. Male. 46 years old. Craniopharyngioma. Lateral hemianopsia of both eyes, dilatation of the sella turcica with and calcium deposit were found, and frontal craniotomy was performed to read the pituitary region. A tumor of walnut-size, consisting of cyst filled with viscous fluid, was extirpated as much as possible, including its wall. After the operation, the PIC was so reduced as to miss even the 70 mm. H₂O level, the patient felt powerless, had headache and vomiting and his urinary output reached 4,000 cc. a day.

![Fig. 10. Case No. 9 X. Ejiri. Craniopharyngioma. Extirpation. (see text).](image)

**DISCUSSION AND SUMMARY**

The changes in PIC, besides pulsation, respiration and body temperature, were studied several days following brain operations to treat several brain diseases as enumerated in the above, and the PIC showed changes characteristic to the diseases have been ascertained.
The so-called Cushing's phenomena,\textsuperscript{12,13} hitherto accepted as the best indices for proving rise of PIC, such as slow pulses, high blood pressure and increased pulse pressure, were not observable in all cases,\textsuperscript{14} perhaps due to the interference of many post-operative factors and the comparatively slow rise of PIC. Only when the PIC approached anything like 1,000 mm.H\textsubscript{2}O, such effects made appearance. Thus, we have been led to deny the possibility of making inferences on the PIC from the pulsation, the respiration and the blood pressure after a brain operation.

Then, what can serve as an index of rising PIC? We must answer that there is nothing that can indicate with precision the height to which the PIC has risen. For example, take the state of consciousness of the patient. Some have illusions and lose orientation at a slight rise of PIC to 500 mm.H\textsubscript{2}O, while others show no signs of headache and talk freely with a PIC of 1,000 mm.H\textsubscript{2}O. So, if there is a correlation between the consciousness of the patient and his PIC, we can make no inference on the height of the latter from the state of the former. My observations have shown that, in the case where the rise of PIC is caused by obturation of the aqueduct of Sylvius or some point of the ventricular system below it, a considerable rise fails to blur the consciousness in most cases, while when a diffusive supratentorial glioma cause the brain edema to invade severely as far as to the subcortical nuclei, a mild rise of PIC to 500 mm.H\textsubscript{2}O is frequently accompanied by hallucinations and other such signs of turbid consciousness. As it is possible in some of such cases to effect improvement in the state of the patient's consciousness, by means of depressing his PIC by 50\% glucose injection or removal of his cerebrospinal fluid, we may surmise that PIC is at least a factor in determining the clarity of the subject's consciousness, even though there is no direct correlation between the two.

Now, the same can be said of headache versus PIC, a high PIC not necessarily accompanying severe headache.\textsuperscript{15,17} There were some cases who did not complain of headache, even under very high PIC and others that had excruciating headache while his PIC was not much perceptibly overnormal. But seeing that when the PIC is reduced in the case of underarable headache, the latter is usually alleviated, an interrelation between headache and PIC cannot be denied. Generally speaking, an adrupt rise in PIC is apt to be accompanied with severe headache but there are exceptions, as reported in the previous communication,\textsuperscript{15} so we cannot make it a rule that acute rise in PIC is always correlated with headache. When a tumor in the vicinity of the dura mater, e.g., in the cerebral cortex, is growing rapidly, in such cases we can only predict that severe headache will develop. In such cases too, however, when the disease becomes chronic after a lapse of some time, it seems that the patient
becomes accustomed to a high PIC and pain sensation and ceases to complain much of headache. This can be affirmed when we think of the cases of brain tumors who complained of severe headache at the onset, but later on their headache had abated with time.

In conclusion, a ward on the effect of 50% glucose solution in lowering PIC is mentioned. This question was discussed by Weedund in 1919 and was applied to human subject by Hadson in the same year for the first time. Thereafter, the question has been in controversy. Dandy refraining from recommending it, asserted that the PIC temporarily lower after the injection but soon rerises, and the secondary brain edema following it causes a rise of the PIC. According to personal observations, the treatment showed marked effect in some diseases, but in other cases was little effective or even raised the PIC, though slightly. It has been also ascertained that the effect lasted only about one hour at the utmost. In particular, the injection hypertonic glucose solution had little effect in the cases with no organic legion in the brain, such as genuine epilepsy and idiocy, even slightly raising the PIC in some cases, while in the cases with severe brain edema, such as malign cerebral tumor and brain abscesses, the PIC dropped perceptibly, reaching the lowest level in 30 minutes, but returning to the original level in one hour. In the cases with risen PIC due to internal hydrocephalus caused by obturation of the aqueduct of Sylvius, as in subtentorial tumor, the effect of hypertonic glucose in-

Fig. 11. Effect of intravenous injection of 50% glucose solution in lowering PIC on various neurosurgical cases. --- Astrocytoma in the cerebellum, --- Brain abscess, --- Glioblastoma multiforme in cerebrum, --- Pinealoma, --- Ependymoma of cerebrum, --- Epilepsy.
jection proved mediocre. Thus, the effect of hypertonic glucose solution injected intravenously in lowering PIC is only short-lived, and considering that its effect is dissimilar according to the identity of the disease, we must take care in using it in only indicated cases. (Fig. 11)

**CONCLUSION**

In this report, the author describes the results of his follow-up studies of PIC following surgical operation of representative cases of genuine epilepsy, benign and malign supratentorial tumors, benign and malign subtentorial tumors, brain abscess, metastatic brain tumor, hypophysial tumor and brain injuries undertaken at the Surgical Clinic of Prof. Katsura, Tohoku University. Besides, the problems of the correlation between PIC, and headache and the state of consciousness and of the action of hypertonic glucose solution in lowering PIC have been discussed.

**References**

1) Suzuki, No to Shinkei (Jap.), 1955, 7, 280.
5) Suzuki, Komiyama & Toyoda, Tohoku Igaku Zasshi (Jap.), 1955, 52, 161.
9) Suzuki, No to Shinkei (Jap.), 1955, 7, 352.
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